3-OPA
Dudley

Distant view of the Observatory and Dwelling House.

ALBANY:
WEED, PARSONS & COMPANY, PRINTERS.
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ANNALS

OF THE

DUDLEY OBSERVATORY.

VOL. I.

ALBANY:
WEED, PARSONS AND COMPANY, PRINTERS.
1866.

STATE OF NEW YORK.

IN ASSEMBLY,
ALBANY, *April* 27, 1865.

Resolved, That 1,500 copies of the Report of the "Dudley Observatory" be printed and distributed under the direction of the Secretary of State.

By order.

J. B. CUSHMAN,
Clerk.

DESCRIPTION

OF THE

BUILDINGS AND INSTRUMENTS,

BY

G. W. HOUGH, A. M.,

DIRECTOR OF THE DUDLEY OBSERVATORY.

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DUDLEY OBSERVATORY.

The establishment of this Institution was first proposed in 1851, by Dr. James H. Armsby. The plan was submitted to Thomas W. Olcott, Esq., who was the first to promise aid to the enterprise. Prof. Amos Dean became interested in the project, and wrote to Prof. O. M. Mitchel of Cincinnati, for advice and coöperation.

PROFESSOR MITCHEL'S REPLY.

Cincinnati, *June* 28*th*, 1851.

Dear Sir: I have received your letter concerning the proposed Observatory at Albany. If I were in a situation to give my entire time to the enterprise, nothing could give me greater pleasure. But my duties and engagements here absorb all my time and efforts.

* * * * * * * *

I could be of little service to you, with my workshop and instruments a thousand miles away. If I had control of such an Observatory as you propose to build, with the improved instruments and machinery, I think great progress could be made in this department of progressive science. * * *

If my life is spared until the meeting of the Association in August, I shall hope to meet you and confer more fully on this subject. O. M. MITCHEL.

Prof. Amos Dean.

On the receipt of Prof. Mitchel's letter, a subscription was opened, and Messrs. Thomas W. Olcott, William H. Dewitt and Ezra P. Prentice, each subscribed

$1,000. Mr. OLCOTT then presented the plan for the establishment of an astronomical observatory to Mrs. BLANDINA DUDLEY, widow of the late Hon. CHARLES E. DUDLEY. Mrs. DUDLEY, with a just appreciation of the object, at once subscribed the sum of $12,000; in consideration of which, the trustees unanimously resolved to give the name of DUDLEY OBSERVATORY to the institution. After this liberal subscription the sum of $25,000 was soon secured in this city.

The act of incorporation was granted by the Legislature in March, 1852. Prof. MITCHEL selected the site, and General STEPHEN VAN RENSSELAER donated the land on which the Observatory building was erected. The trustees have since purchased additional land, amounting in all to about eight acres.

The building was completed in 1854, from plans furnished by Prof. MITCHEL. Mrs. DUDLEY made an additional donation of $13,000 for instruments, which gave a new impetus to the enterprise. Mr. OLCOTT made another donation of $10,000, Mr. J. F. RATHBONE of $5,000, and Mr. WM. H. DEWITT of $3,000. Other liberal subscriptions were received from patrons of science, in different parts of the country, whose names will be found in the appendix.

The Institution was inaugurated on the 28th of August, 1856, at the meeting of the American Association for the Advancement of Science.

The Eulogy on Mr. DUDLEY was delivered by WASHINGTON HUNT, and the inaugural address by EDWARD EVERETT.

On that occasion Mrs. DUDLEY made another donation of $50,000, for a permanent endowment; and, in her last will, made a bequest (not yet received) of $30,000

ditional, for the same object. Mrs. DUDLEY'S donations, luding the bequest, amount to $105,000. The aggregate h donations exceed $150,000, secured mainly through personal efforts of Mr. OLCOTT and Dr. ARMSBY. out $100,000 has been expended on the buildings, truments, grounds, and other objects, and $50,000 has en safely invested as a permanent fund for the support the Institution.

BY BLANDINA, HIS WIFE,
AND DEDICATED TO THE ADVANCEMENT OF
ASTRONOMY.

EULOGY

ON THE

HON. CHARLES E. DUDLEY

BY WASHINGTON HUNT.

EULOGY

ON THE

HON. CHARLES E. DUDLEY.

BY WASHINGTON HUNT.

EULOGY.

The inauguration of two institutions of science at the capital of our State—yesterday the Geological Hall, to-day the Dudley Observatory—is an event of no ordinary interest. Who does not rejoice in contemplating a spectacle, so honorable to the country, so cheering to the friends of learning and social progress? When viewed in connection with the proceedings of the last week—the welcome presence and instructive deliberations of the American Association for the Advancement of Science; the occasion assumes a national dignity and importance, and deserves to be celebrated as an epoch in the history of American science.

The gradual advancement of our country in intellectual culture becomes an object of profound interest to every mind capable of appreciating the influence of knowledge upon the happiness and destiny of mankind. Every new agency by which the boundaries of science are enlarged and the light of philosophy more widely diffused, is welcomed with gratitude as a tribute to civilization, and the revelation of a latent power to gain fresh conquests in the domains of truth. The State of New-York, true to the spirit of the motto inscribed on her shield, has been distinguished from an early period in our history for enlightened efforts to elevate the moral and intellectual condition of her people. We point with pride to the magnificent works by which physical barriers have been surmounted, intercourse unfettered,

commerce expanded, and all the sources of internal prosperity warmed into life and activity; and we honor the memory of the statesmen by whose wisdom and energy these grand results were accomplished. But be it remembered that while thus securing a rapidity of material growth and progress to which history scarcely affords a parallel, we have not been indifferent to the moral and intellectual elements whose harmonious development constitutes the true glory of a state, and entitles it to rank among refined and cultivated nations.

By judicious and liberal legislation we have perfected a system of popular education which brings the means of mental improvement within the reach of all the children of the commonwealth, even the most obscure and destitute. Institutions designed to advance the higher branches of science and learning have been wisely multiplied, and encouraged from time to time by endowments from the public resources. But legislation alone is not sufficient to impart vitality and vigor to a system of education, however perfect the skill displayed in its theory and structure. To insure success individual aid and coöperation are indispensable. Happily for the cause of learning this important requisite has not been withheld. Generous and enlightened men have stepped forward with an ardor, which cannot be too gratefully acknowledged, to second the efforts of the State, and give effect to its aspirations for higher intellectual development.

I consider it alike fortunate for the welfare of the State, and honorable to its fame, that here at the capital, in this ancient city of Albany, we have had a body of cultivated scholars and munificent citizens, of whom any country might be proud, zealously devoted to the cause of letters and science, and active in promoting the increase and

diffusion of knowledge. By their public spirit and well directed exertions, they have excited an interest in the work of education which is already yielding a rich and precious harvest. To them are we indebted for the first foundations of an university designed to embrace within the ample sphere of its operations the entire circle of scientific inquiries; an institution which is generally conceded to be the great intellectual need of our country. From the progress already made in this design, we may safely anticipate its complete success at no distant period. It is truly a noble effort, worthy of generous minds which find their highest happiness in promoting the welfare of their fellow-men. I trust they will not grow weary in the work until they shall have consummated the great object of their labors. Regarding them as public benefactors in the most exalted sense, I must avail myself of this opportunity to express to them my gratitude for the benefits they have conferred upon society.

My chief aim in appearing before you on the present occasion, is to offer a grateful tribute to the memory of one who has gone to his rest, and whose name stands conspicuous among the names of the honored dead who, by their virtues and services, adorned the historic annals of our State. CHARLES E. DUDLEY was a man whose sterling merits would have insured a high place among the first citizens of Greece or Rome, in the virtuous age of either republic, when integrity and patriotism were the only passport to popular eminence.

Before proceeding to enlarge upon his character, permit me to observe that he was the friend of my youth, and that many years of intercourse, during which it was my good fortune to receive numerous proofs of his kindness, gave him a strong hold upon my affections. I was indebted

to him for wise counsels, for generous patronage, and above all for a bright example of manliness and honor which animated his whole life and conduct. The memory of these personal relations revives in my breast feelings of gratitude and devotion which time cannot extinguish. Mr. DUDLEY's career presented a beautiful illustration of the elevating tendency of our free American institutions. Nature had endowed him with a clear, vigorous intellect, and high moral susceptibilities. These characteristics were strengthened by timely culture and the purest social influences. In early life he enjoyed unusual advantages for foreign travel, and became conversant with the manners and institutions of other countries. The principles of commerce, in its grand relations to the public wealth and prosperity, and as a peaceful agency of human progress and civilization, became his favorite subject of investigation. While his acquirements were varied and extensive, he made himself specially familiar with the history of commerce and navigation in ancient and modern times; with the causes which affect their growth and decline; with the practical working of the commercial systems adopted by different nations; and his rich stores of information on these subjects enabled him to render important service to the commercial interests of his own country. His attainments in this department of political economy, and a remarkable faculty for discrimination in deducing from general theories safe practical conclusions, with reference to the actual condition of affairs, qualified him to discuss some of the most difficult questions of commercial policy with a convincing clearness of elucidation. In my intercourse with the world, I have rarely met a statesman whose knowledge on this class of subjects was more complete, or whose observations were more comprehensive and profound.

After devoting some years to the pursuits of commerce, in which his labors were rewarded by abundant success, Mr. Dudley retired from active business and became a citizen of Albany, where he was allied by marriage with one of its most respected and influential families. Among the people of this city, where he passed the remainder of his days, and where his honorable discharge of duty in every relation of life made him "observed of all observers," it would seem unnecessary to dwell upon the virtues which adorned his character, and elicited repeated expressions of public regard and confidence.

In a community so appreciative of merit, it was impossible that such a man should remain in tranquil retirement. From time to time he was called by his fellow-citizens to stations of eminent dignity and importance, and he never failed to discharge his trust with fidelity and capacity. He was chosen more than once to preside over the municipal administration of this city, as its chief magistrate; and in this position he rendered services which are still remembered with gratitude. As a member of the Senate of New York he identified his name with beneficent measures which have contributed largely to the intellectual progress and material prosperity of the State. In him our system of internal improvements found a firm and enlightened supporter. He was an effective advocate of the Erie Canal at a time when that magnificent undertaking was denounced as visionary, and its completion placed in jeopardy by a strong and determined opposition. But I regard it as his highest merit as a legislator for the State, that he was a zealous and constant friend of the cause of education. Every measure calculated to diffuse the blessings of knowledge, whether by the extension of our common school system, or the creation of new

institutions of learning, received from him an earnest and powerful support.

At a subsequent period Mr. DUDLEY was elected to a seat in the Senate of the United States; a station which he filled with honor to himself and advantage to the country. He was one of the most dignified and respected members of that body at a time when CLAY and WEBSTER and CALHOUN gave lustre to the senatorial office. On questions affecting the commercial interests of the country, his thorough knowledge of the laws of trade gave an important weight to his opinions. As a Senator, he was distinguished among his peers for ripe intelligence, true patriotism, and a spirit of candor which inspired confidence in the rectitude of his motives and the soundness of his judgment. It frequently occurs that these sterling qualities are of more value to the country in its legislative bodies, than the most brilliant displays of impassioned eloquence. It was Mr. DUDLEY'S fortune to act a prominent part on the stage of public events, in times of intense political excitement. Though decided in his opinions, adhering always to his avowed principles with unyielding firmness, party spirit never ventured to assail the integrity of his conduct, or to question the purity of his intentions. He cherished warm political attachments, yet was he no partisan, in the ordinary sense. If he loved Cæsar much, he loved Rome more, and regarded the welfare of his country as paramount to the interests of any party.

On several occasions he exhibited a lofty spirit of independence, in defiance of the most powerful political influences. In every relation, public and private, he was governed by a controlling sense of justice, and discharged his duty with that true moral courage which rejects all

fear, except the fear of doing wrong. His personal deportment exhibited that blending of dignity and courtesy which inspires a mingled sentiment of homage and affection. In all the intercourse of life he displayed a refined sense of propriety. Naturally modest and retiring, he avoided no duty, and shrank from no responsibility which a statesman or a citizen can be justly required to assume. He sought no prominence, but accepted the honors which were conferred upon him as a trust for the benefit of his fellow-men.

This is a brief and imperfect outline of the character and career of CHARLES E. DUDLEY. Fifteen years have passed away since he departed this life, loved by all who knew him and most by those who knew him best, honored by his fellow-citizens, and mourned by the country which he had so faithfully served. By the blessing of Providence, his beloved and venerable widow, the partner of his joys and sorrows, and the object of his fondest affections, still survives. To her bereaved spirit, during the long period of her loneliness, the recollection of his virtues and life-long devotion to her happiness, and the hope of reunion in the realms of immortal felicity, have been a source of unfailing consolation.

> "Like lamps in eastern sepulchres,
> Amid my heart's deep gloom,
> Affection sheds its holiest light
> Upon my husband's tomb;
> And as those lamps, if brought once more
> To upper air, grow dim,
> So my soul's love is cold and dead
> Unless it glow for him."

To her has been reserved the pious office of rearing an appropriate monument to his memory. How generously, how nobly this sacred duty has been performed, will be recorded and remembered during all future time! The

recollection of her constancy and munificence will be cherished by coming generations until the earth shall give up its dead. Her tribute of affection to a departed husband is a graceful offering upon the altar of science and truth. In [illegible] a scientific [illegible] to perpetuate his memory, she has built an edifice which points to the heavens and creates an instrument which shall unfold [illegible] the wonders of the [illegible] suitable and [illegible] her own [illegible] the names [illegible] the most [illegible]

THE

USES OF ASTRONOMY.

A

DISCOURSE,

BY

EDWARD EVERETT.

TO

MRS. BLANDINA DUDLEY,

TO THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,

TO THE REGENTS OF THE UNIVERSITY OF THE STATE OF NEW-

YORK, AND TO

THE CITIZENS OF ALBANY, GENERALLY,

THIS DISCOURSE,

DELIVERED ON THEIR INVITATION AND IN THEIR

PRESENCE, AND PUBLISHED AT THE REQUEST OF THE COMMITTEE OF

ARRANGEMENTS FOR THE INAUGURATION OF THE DUDLEY

OBSERVATORY, IS, WITH THE BEST WISHES FOR THE

COMPLETE SUCCESS OF THAT NOBLE EN-

TERPRISE, RESPECTFULLY

DEDICATED BY

EDWARD EVERETT.

BOSTON, *September*, 1856.

DISCOURSE.

-CITIZENS OF ALBANY:

ıbled as we are under your auspices in this ancient spitable city, for an object indicative of a highly ed stage of scientific culture, it is natural in the first to cast an historical glance at the past. It seems to surpass belief, though an unquestioned fact, that than a century should have passed away, after CABOT discovered the coast of North America for England, e any knowledge was gained of the noble river on h your city stands, and which was destined by Provice to determine in after-times the position of the comcial metropolis of the continent. It is true that RAZZANO, a bold and sagacious Florentine navigator in service of France, had entered the Narrows in 1524, ıich he describes as a very large river, deep at its outh, which forced its way through steep hills to the sea. ut, though he, like most of the naval adventurers of that ge, was sailing westward in search of a shorter passage to India, he left this part of the coast without any attempt to ascend the river; nor can it be gathered from his narrative that he believed it to penétrate far into the interior.

Near a hundred years elapsed before that great thought acquired form and substance. In the spring of 1609, the heroic but unfortunate HUDSON, one of the brightest names in the history of English maritime achievement, but then in

the employment of the Dutch East India Company, in a vessel of eighty tons, bearing the very astronomical name of the "Half-moon," having been stopped by the ice in the Polar Sea, in the attempt to reach the East by the way of Nova Zembla, struck over to the coast of America in a high northern latitude. He then stretched down southwestwardly to the entrance of Chesapeake Bay, (of which he had gained a knowledge from the charts and descriptions of his friend, Capt. SMITH,)—thence returning to the North, entered Delaware Bay,—standing out again to sea arrived on the 2d of September in sight of the "high hills" of Neversink, pronouncing it "a good land to fall in with, and a pleasant land to see," and on the following morning, sending his boat before him to sound the way, passed Sandy Hook, and there came to anchor, on the third of September, 1609; two hundred and forty-seven years ago, next Wednesday. What an event, my friends, in the history of American population, enterprise, commerce, intelligence and power,—the dropping of that anchor at Sandy Hook!

Here he lingered a week, in friendly intercourse with the natives of New Jersey, while a boat's company explored the waters up to Newark Bay. And now the great question. Shall he turn back like VERAZZANO, or ascend the stream? HUDSON was of a race and in an employ, not prone to turn back, by sea or by land. On the 11th of September, he raised the anchor of the "Half-moon," passed through the Narrows, beholding on both sides "as beautiful a land as one can tread on;" and floated cautiously and slowly up the noble stream, the first ship that ever rested on its bosom. He passed the Palisades, nature's dark basaltic Malakoff; forced the iron gateway of the Highlands, and anchored on the 14th, near West Point;

swept onward and upward the following day by grassy meadows and tangled slopes, hereafter to be covered with smiling villages;—by elevated banks and woody heights, the destined site of future towns and cities,—*tot egregias urbes*,—of Newburg, Poughkeepsie, Catskill;—on the evening of the 15th arrived opposite "the mountains which lie from the river side," where he found "a very loving people and very old men; and the day following reached the spot, hereafter to be honored by his own illustrious name. One more day wafts him up between Schodac and Castleton, and here he landed and passed a day with the natives,—greeted with all sorts of barbarous hospitality,—the land "the finest for cultivation he ever set foot on," the natives so kind and gentle that, when they found he would not remain with them over night, and feared that he left them,—poor children of nature,—because he was afraid of their weapons, he, whose quarter deck was heavy with ordnance, they "broke their arrows in pieces and threw them in the fire." On the following morning, with the early flood-tide, on the 19th of September, 1609, the Half-moon "ran higher up two leagues above the Shoals," and came to anchor in deep water, near the site of the present city of Albany. Happy, if he could have closed his gallant career, on the banks of the stream which so justly bears his name, and thus have escaped the sorrowful and mysterious catastrophe which awaited him in the Arctic waters, the next year!

But the discovery of your great river and of the site of your ancient city, is not the only event which renders the year 1609 memorable in the annals of America and the world. It was one of those years, in which a sort of sympathetic movement toward great results unconsciously pervades the races and the minds of men. While Hudson

was exploring this mighty river and this vast region for the Dutch East India Company, CHAMPLAIN, in the same year, carried the lilies of France to the beautiful lake which bears his name, on your northern limits;—the languishing establishments of England in Virginia were strengthened by the second charter granted to that colony;—the little church of ROBINSON removed from Amsterdam to Leyden, from which, in a few years, they went forth to lay the foundations of New England on Plymouth Rock;—the seven United Provinces of the Netherlands, after that terrific struggle of forty years, (the commencement of which has just been embalmed by an American historian in a record worthy of the great event,) wrested from Spain the virtual acknowledgment of their independence in the Twelve Years' truce;—and JAMES the First, in the same year, granted to the British East India Company their first permanent charter; corner-stone of an empire destined in two centuries to overshadow the East.

One more incident is wanting to complete the list of the memorable occurrences which signalize the year 1609, and one most worthy to be remembered by us on this occasion. Contemporaneously with the events which I have enumerated,—eras of history, dates of empire, the starting point in some of the greatest political, social, and moral revolutions in our annals, an Italian astronomer, who had heard of the magnifying glasses which had been made in Holland by which distant objects could be brought seemingly near, caught at the idea, constructed a telescope and pointed it to the heavens. Yes, my friends, in the same year in which HUDSON discovered your river and the site of your ancient town, in which ROBINSON made his melancholy Hegira from Amsterdam to Leyden, GALILEO GALILEI, with a telescope, the work of his own hands, discovered the

phases of Venus and the satellites of Jupiter; and now, after the lapse of less than two centuries and a half, on a spot then embosomed in the wilderness, the covert of some of the least civilized of all the races of men, we are assembled, descendants of the Hollanders, descendants of the Pilgrims, in this ancient and prosperous city, to inaugurate the establishment of a first-class Astronomical Observatory.

One more glance at your early history. Three years after the landing of the Pilgrims at Plymouth, (for I delight to trace these kindly synchronisms,) Fort Orange was erected, in the centre of what is now the business part of the city of Albany, and a few years later, the little hamlet of Beverswyck began to nestle under its walls. Two centuries ago, my Albanian friends, this very year, your forefathers assembled, not certainly to inaugurate an observatory, but to lay the foundations of a new church in the place of the rude cabin which had hitherto served them in that capacity. It was built at the intersection of Yonker's and Handelaar's, better known to you as State and Market streets. Public and private liberality coöperated in the important work. The authorities at the fort gave fifteen hundred guilders;—the Patroon of that early day, with the liberality coeval with the name and the race, contributed a thousand;—while the inhabitants, for whose benefit it was erected, whose numbers were small and their resources smaller, subscribed twenty beavers, "for the purchase of an oaken pulpit in Holland." Whether the largest part of this subscription was bestowed by some liberal benefactress, tradition has not informed us. It has however informed us, as I learned a few hours since from Mr. Brodhead, that the corner-stone of the little church was laid by the Rev. Rutger Jacobsen; and that his daughter married

JAN JANSEN BLEECKER, from whom is lineally descended MRS. BLANDINA BLEECKER DUDLEY, to whom we are so largely indebted for this day's celebration.

Nor is the year 1656 memorable in the annals of Albany alone. In that same year your imperial metropolis, which had then recently been incorporated as a city by the name of New Amsterdam, was first carefully surveyed by official authority, and found to contain one hundred and twenty houses and one thousand inhabitants.* In eight years more New Netherland becomes New-York; Fort Orange, with its dependent hamlet, assumes the name of Albany; — a century of various fortune succeeds, — the scourge of French and Indian war is rarely absent from the land, — every shock of European policy vibrates with electric rapidity across the Atlantic, but the year 1756 finds a population of three hundred thousand in your growing province. Albany, however may still be regarded almost as a frontier settlement. Of the twelve counties into which the province was divided a hundred years ago, the county of Albany comprehended all that lay north and west of the city; and the city itself contained but about three hundred and fifty houses.

One more century; another act in the great drama of empire; another French and Indian war beneath the banners of England; a successful revolution, of which some of the most momentous events occurred within your immediate neighborhood; a union of States; a constitution of federal government; your population carried to the St. Lawrence and the great Lakes, and their waters poured into the Hudson; your territory covered with a network of canals and railroads, filled with life, and action, and power, with all

* These historical notices, relative to the discovery of the river by HUDSON, and the foundation of Albany, are for the most part abridged from Mr. BROADHEAD'S excellent history of New-York.

peaceful art and prosperous enterprise, with all s which constitute and advance the civilization population exceeding that of the Union at the Revolution, your own numbers twice as large as largest city of that day, you have met together, just two hundred years since the erection of the h of Beverswyck, to dedicate a noble temple and to take a becoming public notice of the ent of an institution destined, as we trust, to eneficial influence on the progress of useful know- home and abroad, and through that on the general civilization.

vill observe that I am careful to say the progress nce "at home and abroad;" for the study of my in this country, like that of many other branches ural science, has long since, I am happy to add, that point where it is content to repeat the ations and verify the results of European research. s boldly and successfully entered the field of original stigation, discovery and speculation; and there is not a single department of the science in which the names American observers and mathematicians are not cited our brethren across the water, side by side with the ost eminent of their European contemporaries.

This state of things is certainly recent. During the colo- ial period, and in the first generation after the Revolution, o department of science was, for obvious causes, very extensively cultivated in America,—astronomy perhaps as much as the kindred branches. The improvement in the quadrant commonly known as HADLEY'S had already been made at Philadelphia by GODFREY in the early part of the last century, and the beautiful invention of the collimating tele- scope was made at a later period by RITTENHOUSE, an

astronomer of distinguished repute. The transits of Venus of 1761 and 1769 were observed in different parts of the country; orreries, a favorite scientific toy in the last century, were constructed in Philadelphia and Boston; and some respectable scientific essays are contained and valuable observations are recorded in the early volumes of the transactions of the Philosophical Society at Philadelphia, and the American Academy of Arts and Sciences at Boston and Cambridge. But in the absence of a numerous class of men of science to encourage and aid each other, in a state of the country as yet too poor to extend a liberal patronage to the expensive arts, without observatories and without valuable instruments, little of importance could be expected in the higher walks of astronomical research.

The greater the credit due for the achievement of an enterprise commenced in the early part of the present century, and which would reflect honor on the science of any country and any age, I mean the translation and commentary on LAPLACE'S *Mecanique Celeste*, by BOWDITCH; a work whose merit I am myself wholly unable to appreciate, but which I have been led to think places the learned translator and commentator on a level with the ablest astronomers and geometers of the day. This work may be considered as opening a new era in the history of American science. The country was still almost wholly deficient in instrumental power; but the want was generally felt by men of science, and the public mind in various parts of the Union began to be turned towards the means of supplying it. In 1825, President JOHN QUINCY ADAMS brought the subject of a National Observatory before congress. Political considerations prevented its being favorably entertained at that time; and it was not till 1842, and as an incident of the exploring expedition, that an appropriation was made for a *depot* for the

charts and instruments of the navy. On this modest basis has been reared the National Observatory at Washington; an institution which has already taken and fully sustains an honorable position among the scientific establishments of the age.

Besides the institution at Washington, fifteen or twenty observatories have, within the last few years, been established in different parts of the country; some of them on a modest scale, for the gratification of the scientific taste and zeal of individuals, others on a broad foundation of expense and usefulness. In these establishments, public and private, the means are provided for the highest order of astronomical observation, research, and instruction. There is already in the country an amount of instrumental power (to which addition is constantly making), and of mathematical skill on the part of our men of science, adequate to a manly competition with their European contemporaries in astronomy and the branches of science theoretical and applied connected with it. The proceedings of the present meeting of the American Association fully justify this remark. The fruits are already before the world in the triangulation of several of the States, in the great work of the coast survey, in the numerous scientific surveys of the interior of the continent, in the astronomical department of the exploring expedition, in the more recent scientific expedition to Chili; in the brilliant hydrographical labors of the observatory at Washington; in the published observations of Washington and Cambridge; in the general character of the contents of the journal conducted by the Nestor of American Science, now in its eighth lustrum, of the Sidereal Messenger, and the Astronomical Journal; in the National Ephemeris; in the great chronometrical expeditions to determine the longitude of Cambridge, better ascertained than that of Paris

was till within the last year; in the prompt rectification of the errors in the predicted elements of Neptune, in its identification with LALANDE'S missing star, and in the calculation of its ephemeris; in the discovery of the satellite of Neptune, of the eighth satellite of Saturn, and of the innermost of its rings; in the establishment, both by observation and theory, of the non-solid character of Saturn's rings; in the recent remarkable speculations on the nature of the Zodiacal light; in the separation and measurement of many double and triple stars, amenable only to superior instrumental power; in the immense labor already performed in preparing Star Catalogues, and in numerous accurate observations of standard stars; in the diligent and successful observation of the meteoric showers; in an extensive series of magnetic observations; in the discovery of an asteroid and ten or twelve telescopic comets (the latter not the achievement of the stronger sex alone); in the resolution of nebulæ, which have defied everything in Europe but Lord ROSSE'S great Reflector; in the application of electricity to the measurement of differences in longitude, in the corrected ascertainment of the velocity of the electro-magnetic fluid, and its truly wonderful uses in recording astronomical observations. These are but a portion of the achievements of American astronomical science within fifteen or twenty years, and fully justify the most sanguine anticipations of its further progress.

How far our astronomers may be able to pursue their researches, will depend upon the resources of our public institutions, and the liberality of wealthy individuals in furnishing the requisite means. With the exception of the observatories at Washington and West Point, little can be done or expected to be done by the government of the Union or the States; but in this, as in everything else connected

with the patronage of art and science, the great dependence, and may I not add the safe dependence, as it ever has been, must continue to be upon the bounty of enlightened, liberal, and public-spirited individuals.

It is by a signal exercise of this bounty, my friends, that we are called together to-day. The munificence of several citizens of this ancient city, among whom the first place is due to the generous lady, whose name has with great propriety been given to the institution, has furnished the means for the foundation of the Dudley Observatory at Albany. On a commanding elevation, on the northern edge of the city, liberally given for that purpose by the head of a family (VAN RENSSELAER) in which the patronage of science is hereditary, a building of ample dimensions has been erected, upon a plan which combines all the requisites of solidity, convenience and taste. A large portion of the expense of the structure has been defrayed by Mrs. BLANDINA DUDLEY, to whose generosity, and that of several other public-spirited individuals, the institution is also indebted for the provision which has been made for an adequate supply of first-class instruments, executed and to be executed by the most eminent makers in Europe and America; and which, it is confidently expected, will yield to none of their class in any observatory in the world.*

With a liberal supply of instrumental power; established in a community to whose intelligence and generosity its support may be safely confided, and whose educational institutions are rapidly realizing the conception of a university; countenanced by the gentleman who conducts the United States Coast Survey with such scientific skill

* For this description of the Dudley Observatory, I am indebted to a valuable article on American Observatories by Professor LOOMIS in Harper's Magazine for June 1856, p. 49.

[illegible] the men of scienc[illegible] [illegible] mitted to the imme[illegible] [illegible] Dr. B. A. Gould), w[illegible] [illegible] added the advantage [illegible] in the most renowned [illegible] as the editor of th[illegible] [illegible] has shown himself to be [illegible]—under these favorable [illegible] Albany now [illegible] foundations of th[illegible] [illegible]

It is no affectation, however, which leads me to express the regret that the interesting occasion could not have taken place under somewhat different auspices. I feel that the duty of addressing this great and enlightened assembly, comprising so much of the intelligence of the community and of the science of the country, ought to have been elsewhere assigned; that it should have devolved upon some one of the eminent persons, many of whom I see around me, to whom you have been listening the past week, who as observers and geometers could have treated the subject with a master's power; astronomers whose telescopes have penetrated the depths of the heavens, or mathematicians, whose analysis unthreads the maze of their wondrous mechanism. If, instead of commanding, as you easily could have done, qualifications of this kind, your choice has rather fallen on one, making no pretensions to the honorable name of a man of science,—but whose delight it has always been to turn aside from the dusty and thankless paths of active life, for an interval of recreation in the green fields [illegible]ed nature in all her kingdoms,—it is, I presume, [illegible] have desired, on an occasion of this kind, ne[illegible] popular character, than [illegible] on occasion of th[illegible] [illegible]ter, that those

of the subject should be presented which address themselves to the general intelligence of the community, and not to its select scientific circles. For astronomy, perhaps to a greater extent than any other department of natural science, exhibits phenomena, which, while they task the highest powers of philosophical research, are also well adapted to arrest the attention of minds barely tinctured with scientific culture, and even to touch the sensibilities of the wholly uninstructed observer. The profound investigations of the chemist into the ultimate constitution of material nature, the minute researches of the physiologist into the secrets of animal life, the transcendental logic of the geometer bristling in a notation, the very sight of which terrifies the uninitiated, are lost on the common understanding. But the unspeakable glories of the rising and the setting sun; the serene majesty of the moon, as she walks in full-orbed brightness through the heavens; the soft witchery of the morning and the evening star; the imperial splendors of the firmament on a bright unclouded night; the comet, whose streaming banner floats over half the sky,—these are objects which charm and astonish alike the philosopher and the peasant;—the mathematician who weighs the masses and defines the orbits of the heavenly bodies, and the untutored observer who sees nothing beyond the images painted upon the eye.

An astronomical observatory, in the general acceptation of the word, is a building erected for the reception and appropriate use of astronomical instruments, and the accommodation of the men of science employed in making and reducing observations of the heavenly bodies. These instruments are mainly of three classes, to which I believe all others of a strictly astronomical character may be referred. 1st. The instruments by which the heavens are inspected, with a view to discover the existence of those celestial

bodies which are not visible to the naked eye, (beyond all comparison more numerous than those which are,) and to observe the magnitude, shapes and other sensible qualities, both of those which are and those which are not thus visible to the unaided sight. The instruments of this class are designated by the general name of Telescope; and are of two kinds;—the refracting telescope, which derives its magnifying power from a system of convex lenses; and the reflecting telescope, which receives the image of the heavenly body upon a concave mirror.

2d. The second class of instruments consists of those which are designed principally to measure the angular distances of the heavenly bodies from each other, and their time of passing the meridian. The transit instrument, the meridian circle, the mural circle, the heliometer, and the sextant belong to this class. The brilliant discoveries of astronomy are for the most part made with the first class of instruments;—its practical results wrought out by the second.

3d. The third class contains the clock, with its subsidiary apparatus for measuring the time and marking its subdivisions, with the greatest possible accuracy;—indispensable auxiliary of all the instruments, by which the positions and motions of the heavenly bodies are observed, and measured, and recorded.

The telescope may be likened to a wondrous Cyclopean eye, endued with superhuman power, by which the astronomer extends the reach of his vision to the further heavens, and surveys galaxies and universes compared with which the solar system is but an atom floating in the air. The transit may be compared to a measuring rod which he lays from planet to planet and from star to star, to ascertain and mark off the heavenly spaces, and transfer

them to his note book. The clock is the marvelous apparatus by which he equalizes and divides into nicely measured parts a portion of that unconceived infinity of duration, without beginning and without end, in which all existence floats as on a shoreless and bottomless sea.

In the contrivance and the execution of these instruments, the utmost stretch of inventive skill and mechanical ingenuity has been put forth. To such perfection have they been carried, that a single second of magnitude or space is rendered a distinctly visible and appreciable quantity. "The arc of a circle," says Sir J. HERSCHEL, "subtended by one second, is less than the two hundred thousandth part of the radius, so that on a circle of six feet in diameter, it would occupy no greater linear extent than $\frac{1}{5700}$ part of an inch; a quantity requiring a powerful microscope to be *discerned* at all."* The largest body in our system, the sun, whose real diameter is 882,000 miles, subtends, at a distance of 95,000,000 miles, but an angle of a little more than 32′; while so admirably are the best instruments constructed, that both in Europe and America, a satellite of Neptune, an object of comparatively inconsiderable diameter, has been discovered at a distance of 2,850 millions of miles.

The object of an Observatory, erected and supplied with instruments of this admirable construction and at proportionable expense, is, as I have already intimated, to provide for an accurate and systematic survey of the heavenly bodies, with a view to a more correct and extensive acquaintance with those already known, and as instrumental power and skill in using it increase, to the discovery of bodies hitherto invisible, and in both classes of objects to the determination

*Herschel's Outlines of Astronomy, § 131.

of their distances, their times of passing the meridian, their relations to each other, and the laws which govern their movements.

Why should we wish to obtain this knowledge? What inducement is there to expend large sums of money in the erection of Observatories, in furnishing them with costly instruments, and in the support of the men of science employed in making, discussing, and recording, for successive generations, these minute observations of the heavenly bodies?

In an exclusively scientific treatment of this subject, an inquiry into its utilitarian relations would be superfluous,—even wearisome. But on an occasion like the present, you will not, perhaps, think it out of place, if I briefly answer the question what is the use of an astronomical observatory, and what benefit may be expected from the operations of such an establishment in a community like ours?

I. In the first place, then, we derive from the observations of the heavenly bodies which are made at an observatory, our only adequate measures of time and our only means of comparing the time of one place with the time of another. Our artificial timekeepers—clocks, watches, and chronometers—however ingeniously contrived and admirably fabricated, are but a transcript, so to say, of the celestial motions, and would be of no value without the means of regulating them by observation. It is impossible for them under any circumstances to escape the imperfection of all machinery, the work of human hands; and the moment we remove with our timekeeper east or west, it fails us. It will keep home time alone, like the fond traveler who leaves his heart behind him. The artificial instrument is of incalculable utility, but must itself be regulated by the eternal clock-work of the skies.

This single consideration is sufficient to show how completely the daily business of life is affected and controlled by the heavenly bodies. It is they and not our mainsprings, our expansion balances, and our compensation pendulums, which give us our time. To reverse the line of Pope,—

> 'Tis with our watches as our judgments; none
> Go just alike, but each believes his own;—

But for all the kindreds and tribes and tongues of men,—each upon their own meridian,—from the Arctic pole to the equator, from the equator to the Antarctic pole, the eternal sun strikes twelve at noon, and the glorious constellations, far up in the everlasting belfries of the skies, chime twelve at midnight;—twelve for the pale student over his flickering lamp; twelve amid the flaming wonders of Orion's belt, if he crosses the meridian at that fated hour; twelve by the weary couch of languishing humanity; twelve in the star-paved courts of the Empyrean; twelve for the heaving tides of the ocean; twelve for the weary arm of labor; twelve for the toiling brain; twelve for the watching, waking, broken heart; twelve for the meteor which blazes for a moment and expires; twelve for the comet whose period is measured by centuries; twelve for every substantial, for every imaginary thing, which exists in the sense, the intellect, or the fancy, and which the speech or thought of man, at the given meridian, refers to the lapse of time.

Not only do we resort to the observation of the heavenly bodies for the means of regulating and rectifying our clocks, but the great divisions of day and month and year are derived from the same source. By the constitution of our nature the elements of our existence are closely connected with the celestial times. Partly by his physical organization, partly by the habit,—second nature,—of the race from the

dawn of creation, man as he is and the times and seasons of the heavenly bodies are part and parcel of one system. The first great division of time, the *day-night* (nychthemerum), for which we have no precise synonym in our language, with its primal alternation of waking and sleeping, of labor and rest, is a vital condition of the existence of such a creature as man. The revolution of the *year*, with its various incidents of summer and winter and seed-time and harvest, is not less involved in all our social, material and moral progress. It is true that at the poles and on the equator, the effects of these revolutions are variously modified or wholly disappear, but as the necessary consequence, human life is extinguished at the poles, and on the equator attains only a languid or feverish development.* Those latitudes only, in which the great motions and cardinal positions of the earth exert a mean influence, exhibit man in the harmonious expansion of his powers. The lunar period, which lies at the foundation of the *month*, is less vitally connected with human existence and development; but is proved by the experience of every age and race to be eminently conducive to the progress of civilization and culture.

But indispensable as are these heavenly measures of time to our life and progress, and obvious as are the phenomena on which they rest, yet, owing to the circumstance that, in the economy of nature, the day, the month, and the year are not exactly commensurable, some of the most difficult questions in practical astronomy are those, by which an accurate division of time, applicable to the various uses of man, is derived from the observation of the heavenly bodies. I have no doubt that, to the Supreme Intelligence which created and rules the universe, there is a harmony hidden to us in

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*Guyot, Earth and Man, p. 231, et seq.

the numerical relation to each other of days, months, and years; but in our ignorance of that harmony, their practical adjustment to each other is a work of difficulty. The great embarrassment which attended the reformation of the calendar, after the error of the Julian period had, in the lapse of centuries, reached ten (or rather twelve) days, sufficiently illustrates this remark. It is most true that scientific difficulties did not form the chief obstacle. Having been proposed under the auspices of the Roman Pontiff, the protestant world, for a century and more, rejected the new style. It was in various places the subject of controversy, collision and bloodshed.* It was not adopted in England till nearly two centuries after its introduction at Rome; and in the country of the Struves and the Pulkova equatorial, they persist at the present day, for civil purposes, in adding eleven minutes and twelve seconds to the length of the tropical year.

II. The second great practical use of an Astronomical Observatory is connected with the science of Geography. The first page of the history of our continent illustrates this connection. Profound meditation on the sphericity of the earth was one of the main reasons which led Columbus to undertake his momentous voyage, and his thorough acquaintance with the astronomical science of that day was, in his own judgment, what enabled him to overcome the almost innumerable obstacles which attended its prosecution.† In return, I find that COPERNICUS, in the very commencement of his immortal work,‡ appeals to the discovery of America as completing the demonstration of the sphericity of the earth. Much of our knowledge of the

* Stern's Himmelskunde, p. 72.
† Humboldt, Histoire de la geographie, etc. Tom I. p. 17.
‡ Copernicus, de Revolutionibus orbium cœlestium, Fol. 2.

figure, size, density, and position of the earth as a member of the solar system is derived from this science, and it furnishes us the means of performing the most important operations of practical geography. Latitude and longitude, which lie at the basis of all descriptive geography, are determined by observation. No map deserves the name, on which the position of important points has not been astronomically determined. Some even of our most important political and administrative arrangements depend upon the coöperation of this science. Among these I may mention the land system of the United States, and the determination of the boundaries of the country.

I believe that till it was done by the Federal Government, a uniform system of mathematical survey had never in any country been applied to an extensive territory. Large grants and sales of public land took place before the Revolution and in the interval between the peace and the adoption of the Constitution; but the limits of these grants and sales were ascertained by sensible objects, by trees, streams, rocks, hills, and by reference to adjacent portions of territory, previously surveyed. The uncertainty of boundaries thus defined was a never-failing source of litigation. Large tracts of land in the Western country granted by Virginia, under this old system of special and local survey, were covered with conflicting claims, and the controversies to which they gave rise formed no small part of the business of the Federal Court after its organization. But the adoption of the present land system brought order out of chaos. The entire public domain is now scientifically surveyed before it is offered for sale; it is laid off into ranges, townships, sections, and smaller divisions with unerring accuracy, resting on the foundation of base and meridian lines; — and I have

been informed that under this system, scarce a case of contested location and boundary has ever presented itself in court. The general land office contains maps and plans, in which every quarter section of the public land is laid down with mathematical precision. The superficies of half a continent is thus transferred in miniature to the bureaus at Washington;—while the local land offices contain transcripts of these plans, copies of which are furnished to the individual purchaser. When we consider the tide of population annually flowing into the public domain, and the immense importance of its efficient and economical administration, the utility of this application of astronomy will be duly estimated.*

I will here venture to repeat an anecdote which I heard lately from a son of the late Hon. TIMOTHY PICKERING. Mr. OCTAVIUS PICKERING, on behalf of his father, had applied to Mr. DAVID PUTNAM of Marietta, to act as his legal adviser, with respect to certain land claims in the Virginia military district, in the State of Ohio. Mr. PUTNAM declined the agency. He had had much to do with business of that kind and found it beset with endless litigation. "I have never," he adds, "succeeded but in a single case, and that was a location and survey made by General WASHINGTON before the Revolution, and I am not acquainted with any surveys, except those made by him, but what have been litigated."

At this moment, a most important survey of the coast of the United States is in progress; an operation of the utmost consequence, in reference to the geography, commerce, navigation, and hydrography of the country. The entire work, I need scarce say, is one of practical astronomy.

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*See an article on the Public Lands by the author of this Address, American Almanac for 1832, p. 145.

[illegible]

[illegible] described by [illegible] could have arisen. [illegible] boundary between the United States and [illegible] Mexico, where it runs through [illegible] and over pathless mountains, along the [illegible] degree of latitude. The identity of [illegible] may be disputed as in the case of the St. Croix; the [illegible] is too broad for a dividing line; the [illegible] of [illegible], as experience has shown, is uncertain; but a degree of latitude is written on the heavenly [illegible] nothing but an observation is required to read [illegible]

But scientific elements, like sharp instruments, must be handled with care. A part of our boundary between the British Provinces ran upon the forty-fifth degree of latitude; and about forty years ago, an expensive fortress was commenced by the government of the United States at Rouse's Point on Lake Champlain, on a spot intended to be just within our limits. When the line came to be more carefully surveyed the fortress turned out to be on the wrong side; we had been building an expensive fortification for our neighbor. But in the general compromises of the treaty of Washington by the Webster and Ashburton Treaty of the 9th of August, 1842, the fortress was left within our limits.*

Errors still more serious had nearly resulted a few years since in a war with Mexico. By the treaty of Gaudalupe Hidalgo, of the 2d of February, 1848, the boundary line between the United States and that country was in part described by reference to the town of El Paso, as laid down on a specified map of the United States, of which a copy was appended to the treaty. This boundary was to be surveyed and run by a joint commission of men of science. It soon appeared that errors of two or three degrees existed in the projection of the map. Its lines of latitude and longitude did not conform to the topography of the region; so that it was impossible to execute the text of the treaty. The famous Mesilla Valley was a part of the debatable ground, and the sum of ten millions of dollars paid to the Mexican government, for that and for an additional strip of territory on the southwest, was the smart-money which expiated the inaccuracy of the map; the necessary result perhaps of the want of good materials for its construction. Ten millions of dol-

*Webster's Works, Vol. I, pp. 110, 115.

lars would have gone a good way toward the expense of a National Observatory and of a map of the continent, constructed with entire accuracy.

It became my official duty, in London, a few years ago, to apply to the British government for an authentic statement of their claim to jurisdiction over New Zealand. The official Gazette for the 2d of October, 1840, was sent me from the Foreign office, as affording the desired information. This number of the Gazette contained the proclamations issued by the lieutenant-governor of New Zealand "in pursuance of the instructions he received from the Marquess of Normanby, one of Her Majesty's principal Secretaries of State," asserting the jurisdiction of his government over the islands of New Zealand, and declaring them to extend "from thirty-four degrees thirty minutes north, to forty-seven degrees ten minutes south latitude." It is scarcely necessary to say, that south latitude was intended in both instances. This error of sixty-nine degrees of latitude, which would have extended the claim of British jurisdiction over the whole breadth of the Pacific, had apparently escaped the notice of that government.

It would be easy to multiply illustrations of the great practical importance of accurate scientific designations drawn from astronomical observation, in various relations connected with boundaries, surveys, and other geographical purposes; but I must hasten to

III. A third important department, in which the services rendered by astronomy are equally conspicuous. I refer to commerce and navigation. It is chiefly owing to the results of astronomical observation, that modern commerce has attained such a vast extension, compared with that of the ancient [illegible]. I have already reminded you that accurate [illegible] astronomical [illegible] necessarily to the conception

in the mind of COLUMBUS of his immortal enterprise, and to the practical success with which it was conducted. It was mainly his skill in the use of astronomical instruments, imperfect as they were, which enabled him, in spite of the bewildering variations of the compass, to find his way across the ocean.

With the progress of the true system of the universe towards general adoption, the problem of finding the longitude at sea presented itself. This was the avowed object of the foundation of the Observatory at Greenwich,* and no one subject has received more of the attention of astronomers than those investigations of the lunar theory, on which the requisite tables of the navigator are founded. The pathways of the ocean are marked out in the sky above. The eternal lights of the heavens are the only Pharos whose beams never fail; which no tempest can shake from its foundation. Within my recollection, it was deemed a necessary qualification for the master and the mate of a merchant-ship, and even for a prime hand, to be able to "work a lunar," as it was called.† The improvements in the chronometer

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* Grant's History of Physical Astronomy, p. 460.

† The following amusing anecdote is found in BARON ZACH'S *Correspondence Astronomique*, Vol. IV, p. 62. It is a part of the Baron's account of his visit to *Cleopatra's Barge*, which entered the harbor of Genoa in 1817. The Baron was told by the proprietor and commander of the vessel, that his black cook could find the ship's longitude by observation. "'There he is,' said the young man, pointing to a negro at the stern of the vessel, in his white apron, with a fowl in one hand, and a dressing-knife in the other. 'Come here JOHN,' cried the captain, 'this gentleman is surprised at your calculating the longitude; tell him about it.' *Zach.* What method do you employ in calculating the longitude by lunar distances? *The Cook.* It is indifferent to me. I make use of the method of MASKELYNE, LYONS, of WITCHELL, and of BOWDITCH; but I prefer DUNTHORNE, with which I am more familiar and which is shorter.' I could not express my surprise at language like this from a black cook, with a bleeding fowl in one hand, and a larding-knife in the other."

Dr. BOWDITCH in early life, was supercargo of a vessel trading to the East. His captain, being asked, on one occasion, at Manilla, how he had contrived to find his way, in the face of a north-east monsoon, by mere dead reckoning, replied, "that he had a crew of twelve men, every one of whom could take and work a lunar observation as well, for all practical purposes, as Sir ISAAC NEWTON himself, were he alive." During this conversation, Dr. BOWDITCH sat, "as modest as a maid, saying not a word, but holding his slate pencil in his mouth," while another person remarked that, "there was more knowledge of navigation on board that ship, than there was in all the vessels that have floated in Manilla Bay."—Memoir of Dr BOWDITCH, by NATHANIEL INGERSOL BOWDITCH, p. 29.

have in practice, to a great extent, superseded this laborious operation, but Observation remains, and unquestionably will for ever remain, the only dependence for ascertaining the ship's time and deducing the longitude from the comparison of that time with the chronometer.

It may perhaps be thought that astronomical science is brought already to such a state of perfection that nothing more is to be desired, or at least that nothing more is attainable in reference to such practical applications as I have described. This, however, is an idea which generous minds will reject, in this as in every other department of human knowledge. In astronomy, as in everything else, the discoveries already made, theoretical or practical, instead of exhausting the science, or putting a limit to its advancement, do but furnish the means and instruments of further progress. I have no doubt we live on the verge of discoveries and inventions in every department, as brilliant as any that have ever been made; that there are new truths, new facts ready to start into recognition on every side; and it seems to me there never was an age since the dawn of time, when men ought to be less disposed to rest satisfied with the progress already made, than the age in which we live; for there never was an age more distinguished for ingenious research, for novel result and bold generalization.

That no further improvement is desirable in the means and methods of ascertaining the ship's place at sea, no one I think will from experience be disposed to assert. The last time I crossed the Atlantic, I walked the quarter-deck with the officer in charge of the noble vessel, on one occasion, when we were driving along before a leading breeze and under a head of steam, beneath a starless sky at midnight, at the rate certainly of ten or eleven miles an hour. There is something sublime, but approaching the terrible, in such

a scene; the rayless gloom, the midnight chill, the awful swell of the deep, the dismal moan of the wind through the rigging, the all but volcanic fires within the hold of the ship;—I scarce know an occasion in ordinary life in which a reflecting mind feels more keenly its hopeless dependence on irrational forces beyond its own control. I asked my companion how nearly he could determine his ship's place at sea under favorable circumstances. Theoretically, he answered, I think, within a mile; practically and usually within three or four. My next question was, How near do you think we may be to Cape Race?—that dangerous headland which pushes its iron-bound, unlighted bastions from the shore of Newfoundland far into the Atlantic, first landfall to the homeward-bound American vessel.* We must, said he, by our last observation and reckoning, be within three or four miles of Cape Race. A comparison of these two remarks, under the circumstances in which we were placed at the moment, brought my mind to the conclusion, that it is greatly to be wished that the means should be discovered of finding the ship's place more accurately, or that navigators would give Cape Race a little wider berth. Still I do not remember that one of the steam-packets between England and America was ever lost upon that formidable point.

It appears to me by no means unlikely that, with the improvement of instrumental power, and of the means of ascertaining the ship's time with exactness, as great an advance beyond the present state of art and science in finding a ship's place at sea may take place, as was affected by the invention of the reflecting quadrant, the calcula-

* Since the voyage in question was made (in 1845) a light house has been built on Cape Race.

tion of lunar tables, and the improved construction of chronometers.

In the wonderful versatility of the human mind, the improvement, when it takes place, will very probably be made by paths where it is least expected. The great inducement of Mr. BABBAGE to attempt the construction of an engine, by which astronomical tables could be calculated, and even printed by mechanical means and with entire accuracy, was the errors in the requisite tables. Nineteen such errors, in point of fact, were discovered in an edition of TAYLOR'S Logarithms printed in 1796; some of which might have led to the most dangerous results in calculating a ship's place. These nineteen errors (of which one only was an error of the press) were pointed out in the Nautical Almanac for 1832. In one of these *errata* the seat of the error was stated to be in cosine of 14° 18′ 3″. Subsequent examination showed that there was an error of one second in this correction, and accordingly in the Nautical Almanac of the next year a new correction was necessary. But in making the new correction of one second, a new error was committed of ten degrees. Instead of cosine 14° 18′ 2,″ the correction was printed cosine 4° 18′ 2,″ making it still necessary, in some future edition of the Nautical Almanac, to insert an *erratum* in an *erratum* of the *errata* in Taylor's Logarithms.*

In the hope of obviating the possibility of such errors, Mr. BABBAGE projected his calculating, or, as he prefers to call it, his difference machine. Although this extraordinary undertaking has been arrested in consequence of the enormous expense attending its execution, enough has been achieved to show the mechanical possibility of con-

*Edinburgh Review, Vol. LIX, p. 282.

structing an engine of this kind, and even one of far higher powers, of which Mr. BABBAGE has matured the conception, devised the notation, and executed in part the drawings,— themselves an imperishable monument of the genius of the author.

I happened on one occasion to be in company with this highly distinguished man of science, whose social qualities are as pleasing as his constructive talent is marvellous, when another eminent *savant*, Count STRZELECKI, just returned from his Oriental and Australian tour, observed that he found among the Chinese a great desire to know something more of Mr. BABBAGE'S calculating machine, and especially whether like their own *swanpan* it could be made to go into the pocket. Mr. BABBAGE good-humoredly observed that thus far he had been very much out of pocket with it.

Whatever advances may be made in astronomical science, theoretical or applied, I am strongly inclined to think that they will be made in connection with an increased command of instrumental power. The natural order in which the human mind proceeds in the acquisition of astronomical knowledge, is minute and accurate observation of the phenomena of the heavens, the skillful discussion and analysis of these observations, and sound philosophy in generalizing the results.

In pursuing this course, however, a difficulty presented itself, which for ages proved insuperable, and which to the same extent has existed in no other science, namely, that all the leading phenomena are in their appearance delusive. It is indeed true that in all sciences, superficial observation can only lead, except by chance, to superficial knowledge; but I know of no branch in which, to the same degree as in astronomy, the great leading

phenomena are the reverse of true, while they yet appeal so strongly to the senses, that sagacious philosophers in antiquity who could foretell eclipses, and who discovered the precession of the equinoxes, still believed that the earth was at rest in the centre of the universe, and that all the hosts of heaven performed a daily revolution about it as a centre.

It usually happens in scientific progress, that when a great fact is at length discovered, it approves itself at once to all competent judges. It furnishes a solution to so many problems and harmonizes with so many other facts, that all the other *data*, as it were, crystalize at once about it. In modern times we have often witnessed such an impatience, so to say, of great truths to be discovered, that it has frequently happened that they have been found out simultaneously by more than one individual. A disputed question of priority is an event of very common occurrence. Not so with the true theory of the heavens. So complete is the deception practiced on the senses, that it failed more than once to yield to the announcement of the truth; and it was only when the visual organs were armed with an almost preternatural instrumental power, that the great fact found admission to the human mind.

It is supposed that in the very infancy of science, PYTHAGORAS or his disciples explained the apparent motion of the heavenly bodies about the earth, by the diurnal revolution of the earth on its axis. But this theory, though bearing so deeply impressed upon it the great seal of truth, *simplicity*, was in such glaring contrast with the evidences of the senses, that it failed of acceptance in antiquity or the middle ages. It found no favor with minds like those of ARISTOTLE, ARCHIMEDES, HIPPARCHUS, PTOLEMY, or any of the acute and learned Arabian or

mediæval astronomers. All their ingenuity and all their mathematical skill were exhausted in the development of a wonderfully complicated and ingenious but erroneous theory. The great master truth, rejected for its simplicity, lay, disregarded, at their feet.

At the second dawn of science, the great fact again beamed into the mind of COPERNICUS. Now, at least, in that glorious age which witnessed the invention of printing, the great mechanical engine of intellectual progress, and the discovery of America, we may expect that this long hidden revelation, a second time proclaimed, will command the assent of mankind. But the sensible phenomena were still too strong for the theory;—the glorious delusion of the rising and the setting sun could not be overcome. TYCHO DE BRAHE furnished his observatory with instruments superior in number and quality to all that had been collected before; but the great instrument of discovery, which, by augmenting the optic power of the eye, enables it to penetrate beyond the apparent phenomena and to discern the true constitution of the heavenly bodies, was wanting at Uranienburg. The observations of TYCHO, as discussed by KEPPLER, conducted that most fervid, powerful, and sagacious mind to the discovery of some of the most important laws of the celestial motions; but it was not till GALILEO, at Florence, had pointed his telescope to the sky, that the Copernican system could be said to be firmly established in the scientific world.*

On this great name, my friends, assembled as we are to dedicate a temple to instrumental Astronomy, we may well pause for a moment.

There is much, in every way, in the city of Florence to

* It is another interesting coincidence of events in the year 1609, that KEPPLER'S works *de Motu Martis* and *Astronomia Nova*, in which his two first laws are propounded, appeared in this year. I am indebted for this suggestion to Dr. B. A. GOULD.

excite the curiosity, to kindle the imagination, and to gratify the taste. Sheltered on the north by the vine-clad hills of Fiesole, whose Cyclopean walls carry back the antiquary to ages before the Roman, before the Etruscan power, the flowery city (Fiorenza) covers the sunny banks of the Arno with its stately palaces. Dark and frowning piles of mediæval structure, a majestic dome the prototype of St. Peter's, basilicas which enshrine the ashes of some of the mightiest of the dead, the stone where DANTE stood to gaze on the *campanile*, the house of MICHAEL ANGELO still occupied by a descendant of his lineage and name,—his hammer, his chisel, his dividers, his manuscript poems, all as if he had left them but yesterday;—airy bridges which seem not so much to rest on the earth as to hover over the waters they span;—the loveliest creations of ancient art, rescued from the grave of ages again to "enchant the world;"—the breathing marbles of MICHAEL ANGELO, the glowing canvas of RAPHAEL and TITIAN;—museums filled with medals and coins of every age from CYRUS the younger, and gems and amulets and vases from the sepulchres of Egyptian Pharaohs coeval with JOSEPH, and Etruscan Lucumons that swayed Italy before the Romans;—libraries stored with the choicest texts of ancient literature;—gardens of rose and orange and pomegranate and myrtle;—the very air you breathe languid with music and perfume,—such is Florence. But among all its fascinations addressed to the sense, the memory, and the heart, there was none to which I more frequently gave a meditative hour during a year's residence, than to the spot where GALILEO GALILEI sleeps beneath the marble floor of Santa Croce; no building on which I gazed with greater reverence, than I did upon the modest mansion at Arcetri, villa at once and prison, in which that venerable sage, by command of

the Inquisition, passed the sad closing years of his life; the beloved daughter on whom he had depended to smooth his passage to the grave laid there before him; the eyes with which he had discovered worlds before unknown, quenched in blindness;—

> Ahimè! quegli occhi si son fatti oscuri,
> Che vider più di tutti i tempi antichi,
> E luce fur dei secoli futuri.

That was the house "where," says MILTON, (another of those of whom the world was not worthy,) "I found and visited the famous GALILEO, grown old,—a prisoner to the Inquisition, for thinking on astronomy, otherwise than as the Dominican and Franciscan licensers thought."* Great heavens! what a tribunal, what a culprit, what a crime! Let us thank God, my friends, that we live in the nineteenth century. Of all the wonders of ancient and modern art, statues and paintings, and jewels and manuscripts, the admiration and the delight of ages,—there was nothing which I beheld with more affectionate awe, than that poor rough tube, a few feet in length, the work of his own hands, that very "optic glass" through which the "Tuscan Artist" viewed the moon,

> "At evening from the top of Fesolé
> Or in Valdarno, to descry new lands,
> Rivers, or mountains, in her spotty globe:"

that poor little spy-glass (for it is scarcely more) through which the human eye first distinctly beheld the surface of the moon,—first discovered the phases of Venus, the satellites of Jupiter, and the seeming handles of Saturn,—first penetrated the dusky depths of the heavens,—first pierced the clouds of visual error, which from the creation of the world involved the system of the Universe.

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* Milton's Prose Works, Vol. I, p. 313.

There are occasions in life in which a great mind lives years of rapt enjoyment in a moment. I can fancy the emotions of GALILEO, when first raising the newly constructed telescope to the heavens, he saw fulfilled the grand prophecy of COPERNICUS, and beheld the planet Venus crescent like the moon. It was such another moment as that when the immortal printers of Mentz and Strasburg received the first copy of the Bible into their hands, the work of their divine Art;—like that when COLUMBUS, through the gray dawn of the 12th of October, 1492, (COPERNICUS, at the age of eighteen, was then a student at Cracow,)* beheld the shores of San Salvador;—like that when the law of gravitation first revealed itself to the intellect of NEWTON; like that when FRANKLIN saw by the stiffening fibres of the hempen cord of his kite, that he held the lightning in his grasp; like that when LEVERRIER received back from Berlin the tidings that the predicted planet was found.

Yes, noble GALILEO, thou art right, *E pur si muove.* "It does move." Bigots may make thee recant it; but it moves nevertheless. Yes, the earth moves, and the planets move, and the mighty waters move, and the great sweeping tides of air move, and the empires of men move, and the world of thought moves, ever onward and upward to higher facts and bolder theories. The Inquisition may seal thy lips, but they can no more stop the progress of the great truth propounded by COPERNICUS and demonstrated by thee, than they can stop the revolving earth.

Close now, venerable sage, that sightless, tearful eye; it has seen what man never before saw;—it has seen enough. Hang up that poor little spy-glass; it has done its work. Not HERSCHEL nor ROSSE has comparatively done more. Franciscans and Dominicans deride thy discoveries now, but

* Kopernik et ses Travaux, par Jean Czynski, p. 29.

he time will come, when from two hundred observatories in Europe and America, the glorious artillery of science shall nightly assault the skies, but they shall gain no conquests in those glittering fields before which thine shall be forgotten. Rest in peace, great COLUMBUS of the heavens, like him scorned, persecuted, broken-hearted; in other ages, in distant hemispheres, when the votaries of science, with solemn acts of consecration shall dedicate their stately edifices to the cause of knowledge and truth, thy name shall be mentioned with honor!

It is not my intention, in dwelling with such emphasis upon the invention of the telescope, to ascribe undue importance, in promoting the advancement of science, to the increase of instrumental power. Too much, indeed, cannot be said of the service rendered by its first application in confirming and bringing into general repute the Copernican system; but for a considerable time, little more was effected by the wondrous instrument, than the gratification of curiosity and taste by the inspection of the planetary phases, and the addition of the rings and satellites of Saturn to the solar family. NEWTON, prematurely despairing of any further improvement in the refracting telescope, applied the principle of reflection, and the nicer observations now made, no doubt hastened the maturity of his great discovery of the law of gravitation; but that discovery was the work of his transcendent genius and consummate skill.

With BRADLEY in 1741, a new period commenced in instrumental astronomy, not so much of discovery as of measurement.* The superior accuracy and minuteness, with which

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*Dr. BOWDITCH, in his admirable article in the North American Review, Vol. XX, p. [illegible]. The value of BRADLEY'S observations may be estimated from the labor bestowed upon their reduction by BESSELL as late as 1818, in his "fundamenta astronomiæ pro anno MDCCLV, deducta ex observationibus *viri incomparabilis* JAMES BRADLEY."

the motions and distances of the heavenly bodies were now observed, resulted in the accumulation of a mass of new materials both for tabular comparison and theoretical specu-ion. These materials formed the enlarged basis of astro-nical science between NEWTON and Sir WILLIAM HER-IL. His gigantic reflectors introduced the astronomer to ns of space before unvisited, extended beyond all pre- conception the range of the observed phenomena, and it proportionably enlarged the range of constructive ry. The discovery of a new primary planet and its dant satellites was but the first step of his progress into rinth of the heavens. Contemporaneously with his r ons, the French astronomers, and especially LA ICE, with a geometrical skill scarcely if at all inferior to t of its great author, resumed the whole system of NEW-TON, and brought every phenomenon observed since his time within its laws. Difficulties of fact with which he struggled in vain, gave way to more accurate observations, and problems that defied the power of his analysis yielded to the modern improvements of the calculus.

But there is no *ultima Thule* in the progress of science. With the recent augmentations of telescopic power, the details of the nebular theory proposed by Sir W. HERSCHEL with such courage and ingenuity have been drawn in question. Many—most—of those milky patches in which he beheld what he regarded as cosmical matter, as yet in an unformed state,—the rudimental material of worlds not yet condensed,—have been resolved into stars as bright and distinct as any in the firmament. I well recall the glow of satisfaction, with which on the 22d of September, 1847, being then connected with the University at Cambri received a letter from the venerable director of the tory there, beginning with these memorable w

will rejoice with me that the great nebula in Orion has yielded to the powers of our incomparable telescope! * * It should be borne in mind, that this nebula, and that of Andromeda (which has been also resolved at Cambridge) are the last strongholds of the nebular theory."*

But if some of the adventurous speculations built by Sir WILLIAM HERSCHEL on the bewildering revelations of his telescope has been since questioned, the vast progress which has been made in sidereal astronomy, (to which, as I understand, the Dudley Observatory will be particularly devoted,) the discovery of the parallax of the fixed stars, the investigation of the interior relations of binary and triple systems of stars, the theories for the explanation of the extraordinary, not to say fantastic, shapes discerned in some of the nebulous systems,—whirls and spirals radiating through spaces as vast as the orbit of Neptune,†—the glimpses at systems beyond that to which our sun belongs,—these are all splendid results, which may fairly be attributed to the school of HERSCHEL, and will forever insure no secondary place to that name in the annals of science.‡

In the remarks which I have hitherto made, I have had mainly in view the direct connection of astronomical science with the uses of life and the service of man. But a generous philosophy contemplates the subject in higher relations. It is a remark as old at least as PLATO, and is repeated from him more than once by CICERO, that all the liberal arts have a common bond and relationship.§ The different sciences contemplate as their immediate object the different departments

* Annals of the Observatory of Hartford College, p. CXXI.

† See the remarkable memoir of Professor ALEXANDER, "on the origin of the forms and the present condition of [illegible] of stars, and several of the Nebulæ." —Gould's Astron[illegible]

‡ For an [illegible] [illegible]ir W. HERSCHEL on the Sidereal system, [illegible] STRUVE, pp. 23-44.

§ Ar[illegible]

enough of itself to redeem the honors of academical parchment from centuries of learned dullness and scholastic dogmatism.

But the great object of all knowledge is to enlarge and purify the soul, to fill the mind with noble contemplations, and to furnish a refined pleasure. Considering this as the ultimate end of science, no branch of it can surely claim precedence of astronomy. No other science furnishes such a palpable embodiment of the abstractions which lie at the foundation of our intellectual system; the great ideas of time, and space, and extension, and magnitude, and number, and motion, and power. How grand the conception of the ages on ages required for several of the secular equations of the solar system; of distances from which the light of a fixed star would not reach us in twenty millions of years;* of magnitudes compared with which the earth is but a football; of starry hosts, suns like our own, numberless as the sands on the shore; of worlds and systems shooting through the infinite spaces, with a velocity compared with which the cannon ball is a way-worn, heavy paced traveler!

Much, however, as we are indebted to our observatories for elevating our conceptions of the heavenly bodies, they present even to the unaided sight scenes of glory which words are too feeble to describe. I had occasion, a few weeks since, to take the early train from Providence to Boston; and for this purpose rose at two o'clock in the morning. Everything around was wrapt in darkness and hushed in silence, broken only by what seemed at that hour the unearthly clank and rush of the train. It was a mild, serene, midsummer's night, — the sky was without a cloud, — the winds were whist. The moon, then in the

* NICHOL'S Architecture of the Heavens, p. 160.

had just risen, and the stars shone with a re but little affected by her presence. Jupiter, high, was the herald of the day; the Pleiades the horizon shed their sweet influence in the sparkled near the zenith; Andromeda veiled y discovered glories from the naked eye in the he steady pointers far beneath the pole looked up from the depths of the north to their sovereign. was the glorious spectacle as I entered the train. proceeded, the timid approach of twilight became erceptible; the intense blue of the sky began to , the smaller stars like little children, went first st; the sister-beams of the Pleiades soon melted er; but the bright constellations of the west and remained unchanged. Steadily the wondrous trans-ition went on. Hands of angels hidden from mortal shifted the scenery of the heavens; the glories of t dissolved into the glories of the dawn. The blue now turned more softly gray; the great watch-stars t up their holy eyes; the east began to kindle. Faint eaks of purple soon blushed along the sky; the whole lestial concave was filled with the inflowing tides of the orning light, which came pouring down from above in ne great ocean of radiance; till at length, as we reached the blue hills, a flash of purple fire blazed out from above the horizon, and turned the dewy tear-drops of flower and leaf into rubies and diamonds. In a few seconds, the ever-lasting gates of the morning were thrown wide open, and the lord of day, arrayed in glories too severe for the gaze of man, began his state.

I do not wonder at the superstition of the ancient Magians, who in the morning of the world went up to the hill tops of Central Asia, and ignorant of the true God,

adored the most glorious work of his hand. But I am filled with amazement, when I am told that in this enlightened age, and in the heart of the Christian world, there are persons who can witness this daily manifestation of the power and wisdom of the Creator, and yet say in their hearts, "There is no God."

Numerous as are the heavenly bodies visible to the naked eye, and glorious as are their manifestations, it is probable that in our own system there are great numbers as yet undiscovered. Just two hundred years ago this year, HUYGHENS announced the discovery of one satellite of Saturn, and expressed the opinion that the six planets and six satellites then known, and making up the perfect number of *twelve* composed the whole of our planetary system.* In 1729, an astronomical writer came to the conclusion that there might be other bodies in our system, but that the limit of telescopic power had been reached, and no further discoveries were likely to be made.† The orbit of one comet only had been definitely calculated. Since that time the power of the telescope has been indefinitely increased;—two primary planets of the first class, ten satellites,‡ and forty-three small planets revolving between Mars and Jupiter have been discovered, the orbits of six or seven hundred comets, some of brief period, have been ascertained;—and it has been computed that hundreds of thousands of these mysterious bodies wander through our system. There is no reason to think that all the primary planets which revolve about the sun, have been discovered. An indefinite increase in the number of

* Memoirs of the American Academy of Arts and Sciences, New Series, Vol. III, p. 282.

† Admiral SMYTH'S Celestial Cycle, Vol. 1, p. 198.

‡ This computation of the number of satellites discovered since 1729 assumes six as the number of those of Uranus. See J. R. HIND'S Solar System, p. 175.

ıay be anticipated; while outside of Neptune, ır sun and the nearest fixed star, supposing the of the sun to prevail through half the distance, om for ten more primary planets, succeeding each distances increasing in a geometrical ratio. The ıese will unquestionably be discovered as soon as urbations of Neptune shall have been accurately ;—and with maps of the heavens, on which the telescopic stars are laid down, any one of them discovered much sooner.*

It is when we turn our observation and our thoughts ır own system, to the systems which lie beyond it in avenly spaces, that we approach a more adequate conn of the vastness of Creation. All analogy teaches us ıe sun which gives light to us is but one of those counttellar fires which deck the firmament, and that every ing star in that shining host is the centre of a system, st and as full of subordinate luminaries as our own. these suns, — centres of planetary systems, — thousands visible to the naked eye, millions are discovered by the scope. Sir JOHN HERSCHEL, in the account of his operons at the Cape of Good Hope, † calculates that about five d a half millions of stars are visible enough to be *distctly counted* in a twenty foot reflector in both hemispheres. le adds that "the actual number is much greater, there can e little doubt. His illustrious father estimated on one occahat 125,000 stars passed through the field of his forty foot reflector in a quarter of an hour. This would give 12,000,000 for the entire circuit of the heavens, in a single telescopic zone; and this estimate was made under the assumption that

* LEVERRIER, *Compte Rendu*, 5th Oct., 1846, p. 659. Proceedings of American Academy of Arts and Sciences, Vol. I., p. 178.

† Results of Astronomical Observations made during the years 1834-8, at the Cape of Good Hope, p. 381.

the nebulæ were masses of luminous matter not yet condensed into suns.

These stupendous calculations. however, form but the first column of the inventory of the universe. Faint white specks are visible even to the naked eye of a practised observer in different parts of the heavens. Under high magnifying powers, several thousands of such spots are visible,—no longer, however, faint white specks, but many of them resolved by powerful telescopes into vast aggregations of stars, each of which may with propriety be compared with the milky way of our system. Many of these nebulæ, however, resisted the power of Sir. Wm. Herschel's great reflector, and were accordingly still regarded by him as masses of unformed luminous matter. This, till a few years since, was perhaps the prevailing opinion,—and the nebular theory filled a large space in modern astronomical science. But with the increase of instrumental power, especially under the mighty grasp of Lord Rosse's gigantic reflector and the great refractors at Pulkova and Cambridge, the most irresolvable of these nebulæ have given way; and the better opinion now is, that every one of them is a galaxy, like our own milky way, composed of millions of suns. In other words, we are brought to the bewildering conclusion, that thousands of these misty specks, the greater part of them too faint to be seen by the naked eye, are, not each a universe like our solar system, but each a "swarm" of universes of unappreciable magnitude.* The mind sinks overpowered by the contemplation. We repeat the words, but they no longer convey distinct ideas to the understanding.

But these conclusions, however vast their comprehension, carry us but another step forward in the realms of sidereal

* Humboldt's Cosmos, Vol. III, p. 44, Otté's Translation.

astronomy. A proper motion in space of our sun and of the fixed stars, as we call them, has long been believed to exist. Their vast distances only prevent its being more apparent. The great improvement which has taken place in instruments of measurement within the last generation, has not only established the existence of this motion but has pointed to the region in the starry vault, around which our whole solar and stellar system, with its myriad of attendant planetary worlds, appears to be performing a mighty revolution. If, then, we assume that outside of the system to which we belong, and in which our sun is but a star like Aldebaran or Sirius, the different nebulæ of which we have spoken, thousands of which spot the heavens, constitute each a distinct family of universes, we must, following the guide of analogy, attribute to each of them also, beyond all the revolutions of their individual attendant planetary systems, a great revolution, comprehending the whole; while the same course of analogical reasoning would lead us still further onward, and in the last analysis, require us to assume a transcendental connection between all these mighty systems,—a universe of universes, circling round in the infinity of space, and preserving its equilibrium by the same laws of mutual attraction, which bind the lower worlds together.*

It may be thought that conceptions like these are calculated rather to depress than to elevate us in the scale of being; that banished as he is by these contemplations to a corner of creation, and there reduced to an atom, man sinks to nothingness in this infinity of worlds. But a second thought corrects the impression. These vast contemplations

* For popular views of the present state of science in the department of sidereal astronomy, see Sir JOHN HERSCHEL'S Outlines, part III; Himmelskunde volksfasslich bearbeitet von M. A. STERN, pp. 258-319; and Etudes d' astronomie Stellaire, par F. G. W. STRUVE.

are well calculated to inspire awe, but not abasement. Mind and matter are incommensurable. An immortal soul, even while clothed in this "muddy vesture of decay," is in the eye of God and reason, a purer essence than the brightest sun that lights the depths of heaven. The organized human eye, instinct with life and spirit, which, gazing through the telescope, travels up to the cloudy speck in the handle of Orion's sword, and bids it blaze forth into a galaxy as vast as ours, stands higher in the order of being than all that host of luminaries. The intellect of NEWTON, which discovered the law that holds the revolving worlds together, is a nobler work of God than a universe of universes of unthinking matter.

If still treading the loftiest paths of analogy, we adopt the supposition, — to me I own the grateful supposition, — that the countless planetary worlds which attend these countless suns, are the abodes of rational beings like man, instead of bringing back from this exalted conception a feeling of insignificance, as if the individuals of our race were but poor atoms in the infinity of being, I regard it, on the contrary, as a glory of our human nature, that it belongs to a family which no man can number, of rational natures like itself. In the order of being they may stand beneath us, or they may stand above us; *he* may well be content with his place who is made a little lower than the angels." *

Finally, my friends, I believe there is no contemplation better adapted to awaken devout ideas than that of the heavenly bodies; no branch of natural science which bears clearer testimony to the power and wisdom of God, than that to which you this day consecrate a temple. The heart

* For some interesting views of the controversy which had its origin in the ingenious Essay "of the Plurality of Worlds," see Professor BADEN POWELL'S "Essays on the Spirit of the Inductive Philosophy, the Unity of the Worlds, and the Philosophy of Creation."

of the ancient world, with all the prevailing ignorance of the true nature and motions of the heavenly orbs, was religiously impressed by their survey. There is a passage in one of those admirable philosophical treatises of CICERO, composed in the decline of life, as a solace under domestic bereavement and patriotic concern at the impending convulsions of the State, in which, quoting from some lost work of ARISTOTLE, he treats the topic in a manner which almost puts to shame the teachings of Christian wisdom:—

"Praeclare ergo Aristoteles, 'si essent,' inquit, qui sub terra semper habitavissent, bonis et illustribus domiciliis quæ essent ornata signis atque picturis, instructaque rebus iis omnibus, quibus abundant ii qui beati putantur, nec tamen exissent unquam supra terram; accepissent autem fama et auditione, esse quoddam numen et vim Deorum; deinde aliquo tempore, patefactis terræ faucibus, ex illis abditis sedibus evadere in hæc loca quæ nos incolimus, atque exire potuissent; cum repente, terram, et maria, cœlumque vidissent; nubium magnitudinem, ventorumque vim cognovissent, aspexissentque solem, ejusque tum magnitudinem pulchritudinemque, tum etiam efficientiam cognovissent, quod is diem efficeret, toto cœlo luce diffusa; cum autem terras nox opacasset, tum cœlum totum cernerent astris distinctum et ornatum, lunæque luminum varietatem tum crescentis, tum senescentis, eorumque omnium ortus et occasus, atque in æternitate ratos immutabilesque cursus; hæc cum viderent, profecto et esse Deos, et hæc tanta opera Deorum esse arbitrarentur." *

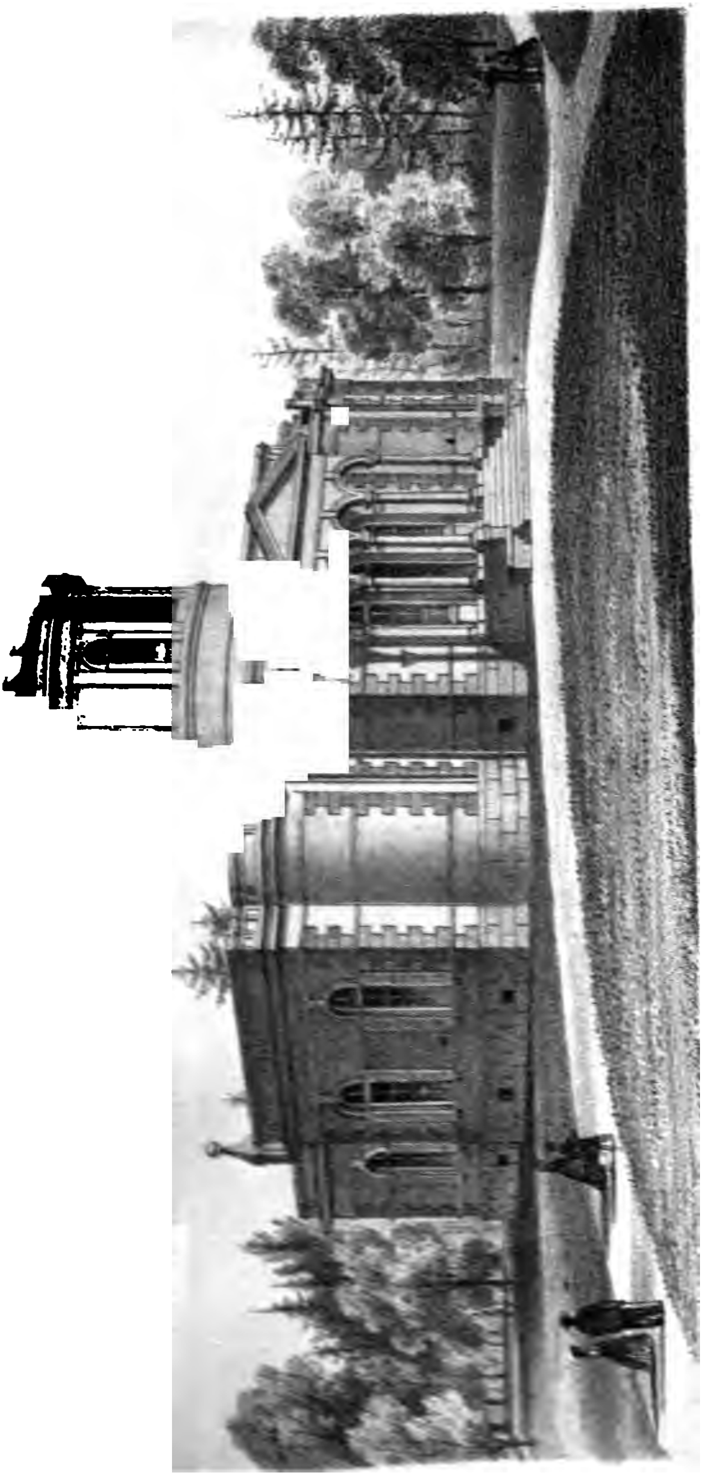
"Nobly does ARISTOTLE observe, that if there were beings who had always lived under ground, in convenient, nay, magnificent dwellings, adorned with statues and pictures, and everything which belongs to prosperous life, but who had never come above ground,—who had heard, however, by

* *CICERO de Natura Deorum*, Lib. II, § 30.

fame and report, of the being and power of the gods,—if at a certain time, the portals of the earth being thrown open, they had been able to emerge from those hidden abodes to the regions inhabited by us; when suddenly they had seen the earth, the seas, and the sky; had perceived the vastness of the clouds and the force of the winds; had contemplated the sun, his magnitude and his beauty, and still more his effectual power, that it is he who makes the day by the diffusion of his light through the whole sky; and when night had darkened the earth, should then behold the whole heavens studded and adorned with stars, and the various lights of the waxing and waning moon, the risings and the settings of all these heavenly bodies, and their courses fixed and immutable in all eternity; when, I say, they should see these things, truly they would believe that there are gods, and that these, so great things, are their works."

There is much by day to engage the attention of the observatory; the sun, his apparent motions, his dimensions, the spots on his disc, (to us the faint indications of movements of unimagined grandeur in his luminous atmosphere,) a solar eclipse, a transit of the inferior planets, the mysteries of the spectrum; all phenomena of vast importance and interest. But night is the astronomer's accepted time; he goes to his delightful labors when the busy world goes to its rest. A dark pall spreads over the resorts of active life; terrestial objects, hill and valley, and rock and stream, and the abodes of men disappear; but the curtain is drawn up which concealed the heavenly hosts. There they shine and there they move, as they moved and shone to the eyes of NEWTON and GALILEO, of KEPPLER and COPERNICUS, of PTOLEMY and HIPPARCHUS; yea, as they moved and shone when the morning stars sang together, and all the sons of God shouted for joy. All has changed on earth; but the glorious heavens

remain unchanged. The plough passes over the site of mighty cities, the homes of powerful nations are desolate, the languages they spoke are forgotten; but the stars that shone for them are shining for us; the same eclipses run their steady cycle; the same equinoxes call out the flowers of spring and send the husbandman to the harvest; the sun pauses at either tropic as he did when his course began; and sun and moon, and planet and satellite, and star and constellation and galaxy, still bear witness to the power, the wisdom, and the love which placed them in the heavens, and upholds them there.



DESCRIPTION

OF THE

OBSERVATORY.

Description of the Buildings and Instruments.

The Dudley Observatory is situated in the northwestern portion of the City of Albany, on an elevation, about 150 feet above the mean tide in the Hudson River. It is distant from the flagstaff on the State Capitol 4931 feet, and the bearing of the latter is 23° 18′ 40″ S. W. from the center of the dome.

The site for the building is probably one of the best that could have been chosen in the vicinity of the city; being easy of access, and at the same time sufficiently remote, as to be free from every disturbing influence. The horizon is clear and unobstructed in every direction, and the position is such as to preclude all possibility of interference, if in future years, the adjoining lands should be occupied for building purposes.

In the plane of the meridian we have an uninterrupted view to the south for more than 12 miles. And we have taken advantage of this circumstance in the establishment of two meridian marks, distant six and twelve miles respectively. In the locating of these marks, I am indebted to the kind assistance of Mr. EDMUND BLUNT, of Brooklyn. To the north, the brow of a hill, about one mile distant, affords an admirable site for the erection of a stone pier, on which could be mounted a small sphere of mercury, like an ordinary thermometer bulb. This would probably be distinctly visible at all times of the day, and would be a fixed point for reference.

The grounds comprise about eight acres, and include the whole of the more elevated portion of the hill, which slopes off gradually in every direction. The surface soil is of a yellow loam, or more correctly, moulding sand. In some portions, at the distance of two or three feet below the surface, a bed of sand and gravel is found of about one foot in thickness. Beneath this is fine sand interspersed with layers of clay.

ATORY.

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The grounds have been partially laid out with walks, and several hundred beautiful shade trees have been planted, in situations best calculated to protect the buildings from the influence of the wind.

The observatory occupies the central and most elevated portion of the hill. The dwelling house is situated near the main entrance to the grounds, at a distance of 320 feet from the Observatory. It is built of brick, and is 42 feet by 50 feet; being three stories high, with a basement.

The gas-works, used for manufacturing gas, after the plan of Mr. AUBIN, is distant 270 feet, and is about 30 feet lower. The Lodge occupied by the Janitor is distant 380 feet, and stands 10 feet lower than the observatory. The New York Central Rail Road, passes around the northeast corner of the grounds. During the passage of a train of cars, a slight tremor is noticeable when making observations with an artificial horizon, or the declinometer. In fact, so delicate is the latter instrument, that the comparative amount of the disturbance is readily read from the fixed scale, varying from 0″.25 to 1″.5, depending on the distance of the disturbing cause. It is even perhaps possible, to determine in absolute numbers, the hight of one of these disturbing waves. But the problem is one of curiosity, rather than of scientific value.

From a careful and extended series of observations with the Olcott Meridian Circle and the Transit instrument, made especially for this purpose, we have become fully satisfied that this tremor has no appreciable effect on the stability and adjustments of the instruments, or on the accuracy of astronomical observations. Aside from direct observation, the uniform value of the Level and Azimuth errors, show conclusively that the disturbance from this cause is inappreciable; since these quantities are as constant, as for any instrument of which we have the published records.

f. Library, 23 feet 3 inches, by 17 feet 6 inches, with cases for books on the east and west sides.

g. Computing Room, 10 feet 4 inches, by 14 feet.

h. Chronograph Room, 8 feet 6 inches, by 10 feet 4 inches.

i. Cabinet.

j. Hall leading to the cellar.

k. Computing Room, 10 feet 4 inches, by 14 feet.

l. Sleeping Room, 8 feet 6 inches, by 10 feet 4 inches.

m. Cabinet.

n. Hall, communicating with side entrance.

o. Clock Room; pier for standard sidereal clock.

p. p'. Collimator piers for Olcott Meridian Circle.

y y'. Collimator piers for Transit.

t. t. Olcott Meridian Circle piers.

t'. t'. Transit piers.

x. Railway track, for observing chair and reversing apparatus.

x'. Railway for Transit.

r. Turn table, for the Olcott Meridian Circle reversing apparatus.

a' a.'' Side entrances.

s. Stairs leading to cellar.

The stars show the position of the gas burners.

Directly opposite to the front entrance, is a niche cut in the base of the Equatorial pier, in which is placed a bust in marble, executed by PALMER, of the Hon. CHARLES E. DUDLEY. On the right of the entrance is a marble dial of the magnetic mean-time clock, the pendulum of which occupies the left of the entrance. Near the middle of the east and west sides of the hall, are portraits in oil and marble slabs, commemorative of the former director, Prof. O. M. MITCHEL, and the assistant astronomer, Mr. AUGUST SONTAG. On the north

For turning the dome, a series of toothed cast-iron pla having a radius of 11 feet, are bolted fast to the upper b plate, forming an immense contrate cog-wheel, 22 feet diameter. A section of this bed-plate and cog-wheel shown in the preceding figure; which also exhibits the ge ing employed for communicating motion to the dome.

The wheel gearing into the bed-plate is 2 ft. 7 in. diameter. This again is geared into a pinion 6 inches diameter, carrying a cog-wheel of the same size as the forn which again is geared into a pinion of one foot in diame to which motion is communicated by means of the cr wheel. The whole of this gearing is let into the wall; handle wheel alone being on the outside.

On the inside of the dome, guides are attached to the lo bed-plate to keep it in its place, and to prevent its being turbed by heavy gales of wind. The openings for the t scope are 4 feet wide, extending from 3 degrees beyond zenith to as many below the horizon; the entire apert being available. The shutters consist of two pairs, one] on the side and one on the top. The upper shutters opened by means of ropes passing over pulleys on the (side, and entering the dome on the sides. They are ɩ nearly counterpoised, so that but little effort is necessary raise them. The side shutters are secured by spring bo and are opened from the floor, by raising the bolts by mea of small cords passing over pulleys. The opening and closi is very expeditious, since it requires less than two minutes accomplish it. Besides these openings, the dome is provid with seven windows, arranged at equal distances apa When these are opened, it requires but a few minutes equalize the inside and outside temperature, which is a grea desideratum in observations on difficult objects. Near th top of the side opening, a half inch iron rod connects th

PLATE II.

two portions together, to secure greater strength and durability. It seldom happens that the rod is directly in the field of vision, and when it does occur, it makes but little difference; since the amount of light cut off is so small as not to be noticable.

On the outside of the dome, and extending nearly around it, is an iron walk and railing; this is occasionally used for making observations with the Comet-seeker. From it we have a magnificent view of the city, river, and surrounding scenery.

The foundation pier, for supporting the Equatorial, is ten feet square, built of limestone laid in cement. The foundation is twelve feet below the surface of the cellar, resting on a bed of coarse sand and gravel. This makes the whole height of the pier, to the base of the cap-stone about 40 feet. The Equatorial telescope is supported on a block of Lockport limestone of the following dimensions: base, 2 ft. 3 in. by 5 ft. 11 inches; height, 8 ft. 10 in. on the north side, by 6 ft. 1 in. on the south. At the height of 6 feet from the base, the size is 1 foot by 3 ft. 6 in. The general shape of the pedestal will best be understood by reference to the drawing, Plate I*a*.

The Equatorial Refractor.

A perspective view of this instrument is seen in Plate I*a*. The object-glass was made by Mr. HENRY FITZ, of New York city; and is of 13 inches clear aperture. The focal length is 15 feet 2 inches. The mountings are mostly of cast iron. The distance from the object-glass to the center of the polar axis is 8 feet; and from the eye end to the same point 7 feet 2 inches. The center of motion of the telescope, is 10 feet 2 inches above the floor of the dome. The tube is of mahogany, constructed by gluing together narrow strips of about one

inch in width. Two wooden rods attached to the sides of the tube, by means of a universal joint near the middle or center of motion, serve to counteract the flexure, and preserve the balance of the instrument. These rods are also used as handles by which to direct the telescope.

The distance from the center of the cast-iron cradle, in which the tube rests, to the center of the polar axis, is 19 inches. The whole length of the equatorial axis is 6 feet 10 inches. The telescope is poised with reference to this axis, by a brass cylinder attached at its extremity.

The polar axis is 3 feet in length, and 6 inches in diameter; it is supported on 4 friction wheels 3½ inches in diameter. The bed-plate on which the polar axis rests, is of cast-iron 2 feet 10 inches long, 9½ inches wide, and one inch thick; this is firmly bolted to the upper surface of the stone pier. The iron frame for supporting the telescope is 2 feet 8 inches long, 8 inches wide, and 2¾ inches thick. This frame is fastened to the bed-plate by 6 steel screws. The instrument is provided with the necessary screws, for adjusting the azimuth and inclination of the polar axis. The lower end of the polar axis rests against a strong steel screw, by means of which the necessary adjustment can be made.

The circles for right ascension and polar distance, are each 20 inches in diameter, made of cast-iron inlaid with a rim of brass. They are each read by two verniers, the right ascension to seconds of time, and the declination to 20 seconds of arc.

Sidereal motion is communicated to the telescope, by means of a clock regulated by a fan, and half-seconds pendulum.

The finder telescope is 34.5 inches focal length, and 2 inches aperture.

There are six negative eye pieces varying from a power of 90 up to 800.

The parallel wire micrometer is of the usual form. The position circle is 5 inches in diameter, and is read by two verniers to minutes of arc. The head of the micrometer screw is divided into one hundred equal parts, each being a little less than one-tenth of a second of arc. The value of one revolution of the screw is 11″.670 at 60° Fahrenheit.

The micrometer eye pieces are six in number, varying from a power of 100 up to 1000.

Gas burners, connected with flexible rubber tubes, are attached to the pier for illuminating the micrometer wires, and for reading the circles. On the south side of the dome, a sidereal clock is set in the wall, which can be regulated by electrical connection with the standard. Wires are also connected with the telescope tube, for recording observations on the chronograph.

The Olcott Meridian Circle.

This instrument is mounted in the east wing of the building. The foundation of the piers is on a bed of sand and gravel, about 10 feet below the floor of the cellar. The base, for supporting the piers, is built of limestone laid in cement, and is 8 feet 3 inches by 6 feet 3 inches. There is a cap-stone placed on the top, with the upper surface on a level with the floor, of the following dimensions: length, 8 feet 6 inches; breadth, 6 feet 5 inches; and thickness, 1 foot. This cap-stone weighs about four and three-quarter tons. In the center of the cap-stone, a quadrangular hole is cut, of 15 inches by 18 inches, in which the artificial horizon is placed.

The piers on which the instrument is mounted are of Lockport limestone, and are of the following dimensions: base, 6 feet by 2 feet 4 inches; height, 9 feet 4 inches; size at top, 2 feet by 3 feet 6 inches. They are sloping on t^h^ sides; the curve commencing at the bottom and exte

to half the height of the pier. The radius of curvature for the north and south surfaces is 9 feet, for the inner surface, 30 feet.

The weight of each pier is estimated at nearly seven and one-half tons. From these dimensions, it would appear that they are among the largest in use in any observatory, and are probably the largest to be found of limestone.

There are two collimator piers, one north and the other south, at a distance of 14 feet from the center of the axis of the meridian circle. They have a base of 2 feet by 3 feet, and are built from the foundation of solid blocks of limestone, well cut on the upper and lower surfaces, and for the portion rising above the floor, likewise on the sides.

The slits for both meridian rooms are 2 feet wide, beginning at the north and south sides at 5 feet 8 inches above the floor. These are provided with six shutters each, four for the roof and one for each end. The roof shutters are opened and closed by a system of gearing, placed between the roof and ceiling, being nearly all hidden from sight. Two vertical rods, with cranks attached, are fastened to the inside walls; by turning these cranks the middle shutters are elevated, leaving the opening entirely free and unobstructed. Behind the collimator-piers are also vertical shafts by which the remaining two shutters are raised. The end shutters are secured by spring bolts, and are easily opened by detaching a catch. It would be impossible to give an adequate idea of this machinery without the necessary drawings. We merely add, that it is so arranged, that any shutter can be left open at pleasure, while the others remain closed; but in opening, it is necessary to begin with the south middle shutter. They are found to be perfectly tight and weather-proof. The only objection is the labor necessary to open and close them, and their liability to occasionally get out of order.

PL

E.

Plate I*a*, is a perspective view of the Olcott Meridian Circle, as seen from the north east. The drawing is on a scale of $\frac{1}{16}$.

The telescope is of 10 feet focal length, and the objective is of 8 inches clear aperture. It was made by Pistor and Martins, of Berlin, and completed in 1856.

The circles are of brass, 36 inches in diameter. The outer rim is inlaid with a strip of silver, having a slight inclination to the axis, on which are engraved the divisions. They are divided to 2′ of arc; every degree is numbered, and every half degree and decade of minutes is so marked, that the minutes in the field are at once recognized. On the outer rim of the circles is engraved every decade of degrees. In regular observations these are not used, since the degrees are known by the finder circles without the necessity of a second reading.

Each circle is read by four microscopes, placed at distances of 90° apart, passing through, and firmly attached to the stone piers. The head of the micrometer screws are divided into 60 equal parts, and read at once seconds of arc. The bisection of the divisions on the circles, is effected by means of two parallel wires, separated by a distance of about 20″. The space between these two wires is bisected by the division, when the seconds and tenths are read from the micrometer screw-head on the outside. It is our custom to make three bisections and readings for each microscope, but only the mean, mentally determined, is recorded in the note book. In the field of the microscope, there is also a series of notches intended to assist the eye in recognizing the proper minute. These are not essential, since it is seen at a glance whether the minute is even or odd; and if there should be any doubt, the micrometer-head reading will at once decide the point. In the drawing, plate I*a*, the letters *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, show the position of the microscopes; only *c*, *d* and *g*, *h*, are visible.

The microscopes are 25 inches in length. They are so mounted, however, that the metal tube may expand and contract from the effect of temperature without disturbing the focal distance of the lenses.

The illumination of the circles, and field of the telescope, is effected by gas burners indicated by *v*, *v*. These burners are placed at a distance of 5 feet 10 inches from the extremity of the axis. The light for illuminating the circle passes through prisms fixed in the stone pier, near the extremity of the axis, by which it is directed on a polished silver reflector inclined at an angle of 45°, mounted in the outer tube of the microscope, by which it is reflected on the limb of the circle.

It was soon found that these reflectors were liable to tarnish, and absorbed a large proportion of the light. We have accordingly removed them, and substituted plain glass mirrors, which never tarnish and give a much better illumination. They are a great improvement on the silver reflectors, since their adjustments need never be disturbed to polish, as is the case with metal. These reflectors or mirrors are perforated in the centre, for observing the limb of the circles through the microscopes.

The supporting axis of the telescope is 3 feet 5 inches in length, and the portions resting on the supporting levers are 6.4 inches in diameter. The central cube, which is fastened to the tube and axis, is 11.4 inches, and the tube and supporting axis, where they are fastened to the cube, are each 12.4 inches in diameter. At the objective and eye ends, the tube is 8.4 inches in diameter; the axis rests on two steel wheels 3.5 inches in diameter, set in the supporting levers *j*, *j*.

The diameter of the pivots is 2.5 inches. By means of the counterpoises *i*, *i*, nearly the whole weight of the instrument is taken off the Y's; an excess of a few pounds being sufficient to keep it in position.

The central cube is provided with two caps which can be unscrewed at pleasure, leaving an opening of two inches in diameter. When the telescope is directed to the zenith or nadir, the collimator-telescopes can be adjusted without the necessity of disturbing the meridian circle.

The finder circles *o*, *o*, are 10 inches in diameter, and are attached to the sides of the tube near the eye end; they are divided to 30′, and are read by means of verniers to 1′ of arc.

The observing couch *s*, plate I*a*, is built of wrought iron, and is so arranged that the observer can elevate himself to any required angle of position while in the act of observing.

EXPLANATION OF PLATE I*a*.

a, *b*, *c*, *d*, *e*, *f*, *g*, *h*, Microscopes.

i, *i*, Counterpoises.

j, *j*, Supporting arms.

k, Hand rod for moving the telescope in zenith distance.

o, *o*, Finding circles.

p, *p*, Conical pins in the declinometer arm.

q, Brass cap on cube.

r, Turn table, for reversing apparatus.

s, Observing chair.

t, Declinometer telescope.

u, Declinometer arm, for giving angular motion to the small telescope *t*.

v, *v*, Gas burners for the illumination of the circles and wires.

The illumination of the wires in the focus of the telescope is effected by receiving the light on a series of prisms inside the tube, after it has passed through the axis, which is perforated for this purpose. There are two modes of illumination, namely, bright lines on a dark field, and dark lines on a bright

field. The amount of the illumination is regulated by means of a screw head *e*, plate 2, placed near the eye end. There is also an independent apparatus, consisting of different colored glasses placed on the slide *i*, plate 1, outside and opposite to the ends of the axis. This is not essential, however, since the illumination is more easily regulated by the observer, at the eye end. In our asteroid and zone work, it was found desirable to devise some mode by which the illumination could be instantly varied at the pleasure of the observer. This has been satisfactorily accomplished by means of a simple apparatus, which is made to shut off the whole or a portion of the light, depending on the motion of a small lever.

The Y-pieces on which the pivots rest are of brass; the mode of attachment to the stone pier, will best be understood by reference to plate 1, fig. 2, drawn to one-third the full size.

y, Piece on which the pivots rest.

h, *h*, Set screws, for holding the Y's in position.

e, *e*, *g*, Screws for adjusting the level.

d, Steel guide, resting against the end of the pivot.

f, *f*, Screws for adjusting the azimuth.

The Y-pieces are the same on both sides, with the exception that one is adjustable in level, and the other in azimuth.

Plate 1, fig. 1, is a drawing of the spirit-level on a scale of $\frac{1}{12}$.

a, *a*, the arms carrying the inverted Y's.

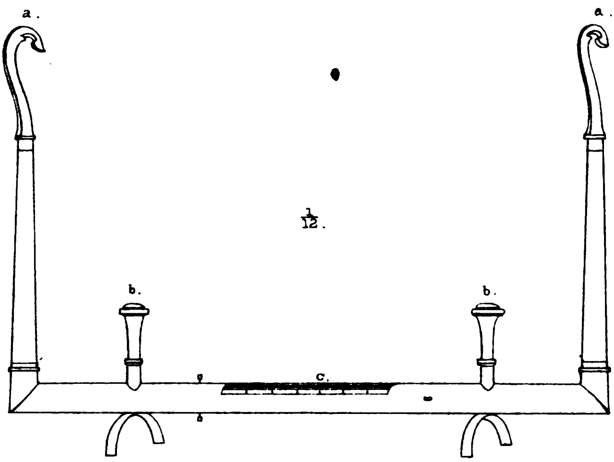
c, the level tube, and divided scale.

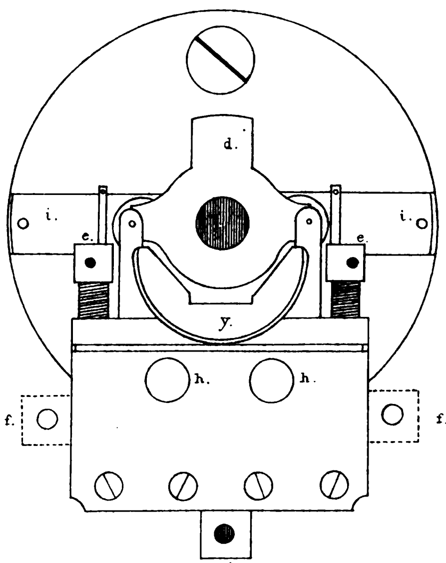
b, *b*, handles.

In the determination of the level error, the meridian circle telescope is turned to a horizontal position, and the level is hung on the pivots, when the position of the bubble is read from the graduated scale.

The level error is also found in the usual way, by directing

Plate 1.





$\frac{1}{3}$.

Weed, Parsons & Co., Albany, N.Y.

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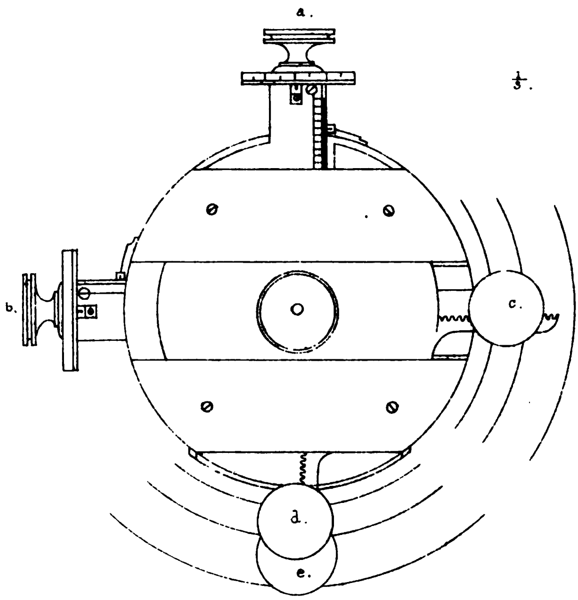
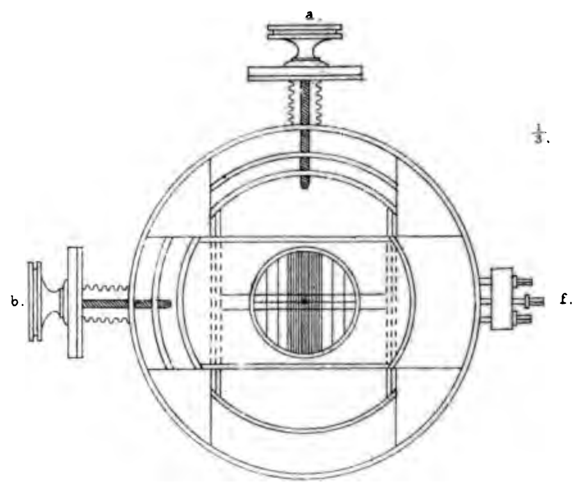
Plate 2.





Lith. of Weed, Parsons & Co., Albany, N.Y.

the telescope to the nadir and observing the reflected image of the middle wire.

Plate 2, exhibits the eye end of the telescope drawn on a scale of one-third the full size.

a, Horizontal micrometer-screw, used in the determination of the nadir point, and for measuring the difference of declination between close circumpolar stars.

b, Vertical micrometer-screw, used in the determination of the collimation and level errors.

c, Screw-head for giving horizontal motion to the eye piece.

d, Screw-head for giving vertical motion to the eye piece.

e, Screw-head for regulating the illumination of the wires.

f, *f*, *f*, Screws for adjusting the collimation.

The transit wires are nineteen in number, arranged in three groups of five each, with two separate ones on each side. The distance between the groups is five seconds of time, between the wires in each group, 2.5 seconds.

The vertical micrometer-plate, moved by the screw *b*, carries a single wire, which is put in coincidence with the middle wire of the system, when not in use.

The horizontal micrometer-plate, moved by the screw *a*, carries a system of three equi-distant wires, the middle one of which is put in coincidence with the fixed horizontal wire.

The value of one revolution of the screws *a* and *b* is 18″.76, at 60° Fahrenheit. The integer number of revolutions is read from a scale on the outside of the tube, and the fractions, from the screw head, which is divided into 100 equal parts.

Plate 3, shows the apparatus employed for giving slow motion to the telescope in zenith distance.

The scale is $\frac{1}{3}$ the full size.

b, Brass frame for supporting the apparatus, firmly attached to the inner face of the west pier.

x, Clamp arm connected with the supporting axis of the meridian circle.

d, *d*, Cog-wheel gearing, for giving motion to the screw *s*.

s, Screw attached to the clamp arm *x*.

k, Hand rod connected with the cog-wheel *d*.

p, *p*, Small brass drums, on which the cords, supporting the weights *w*, *w*, are wound.

c, *c*, Small pulleys.

The use of the brass drums *p*, *p*, is to regulate the amount of motion of the meridian circle in zenith distance, in zone work.

These drums are provided with ratchet wheels, so that the length of the cord left free to move can be regulated at pleasure.

l, Support for the hand rod *k*.

Plate 4, shows a portion of the inside face of the west pier; scale, $\frac{1}{12}$ the full size.

j, Arm for supporting the telescope, showing the manner of resting the axis.

x, Clamp.

m, Hand rod for tightening the clamp *x* on the axis.

a, *b*, *c*, *d*, Microscopes.

Plate 5, shows the inside face of the west pier, on a scale of $\frac{1}{16}$ the full size.

a, *b*, *c*, *d*, Microscopes.

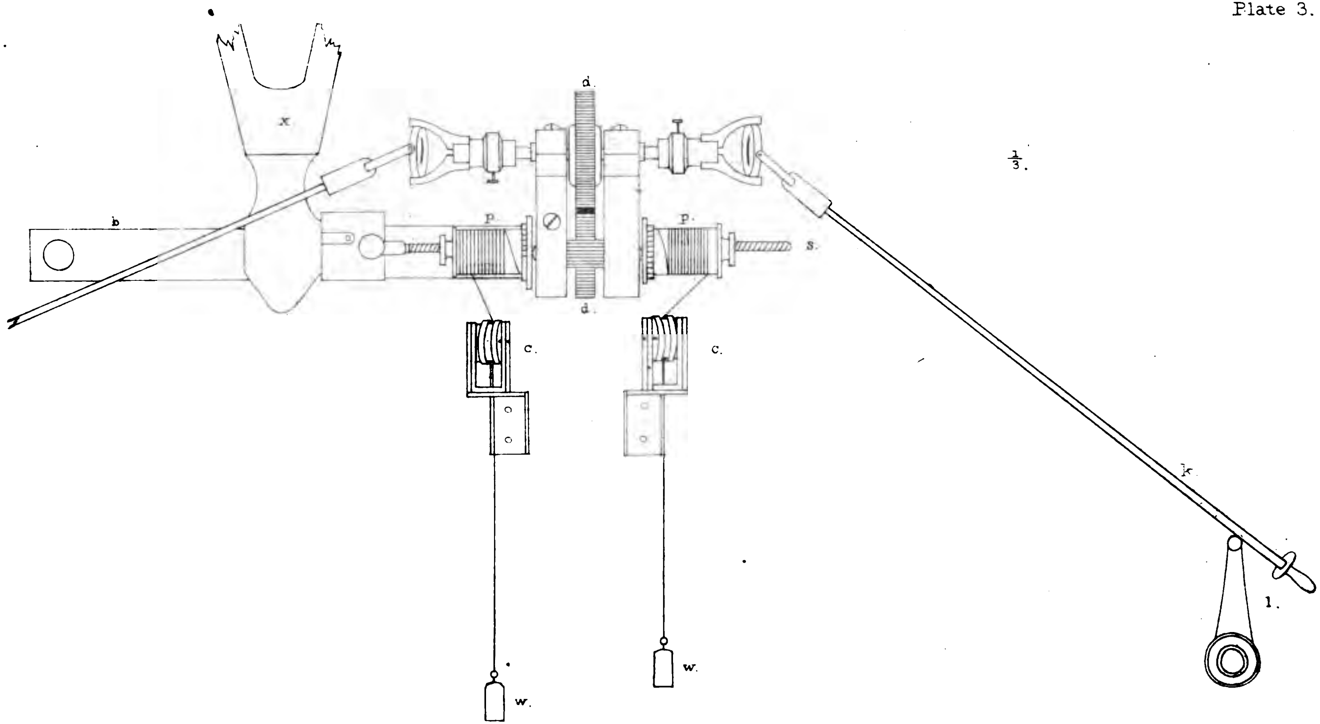
k, *k*, Hand rods for giving slow motion in zenith distance.

l, *l*, Support for the rods *k*, *k*.

Plate 6, is a vertical and horizontal view of one of the collimators, drawn on a scale of $\frac{1}{6}$.

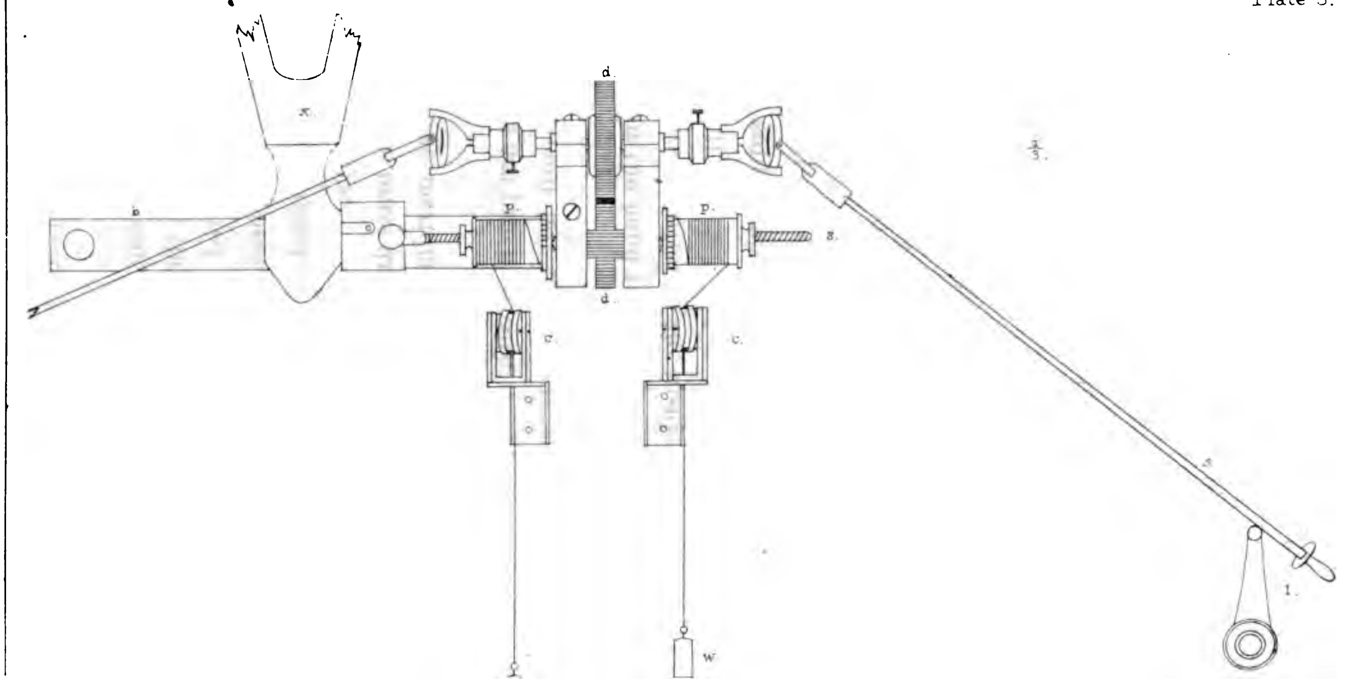
The stone piers on which are mounted the collimator telescopes have an elliptical hole cut in the cap stone, in which the frame supporting the telescopes is placed. The frame is

Plate 3.



Weed Parsons & Co. Albany N.Y.

Plate 3.



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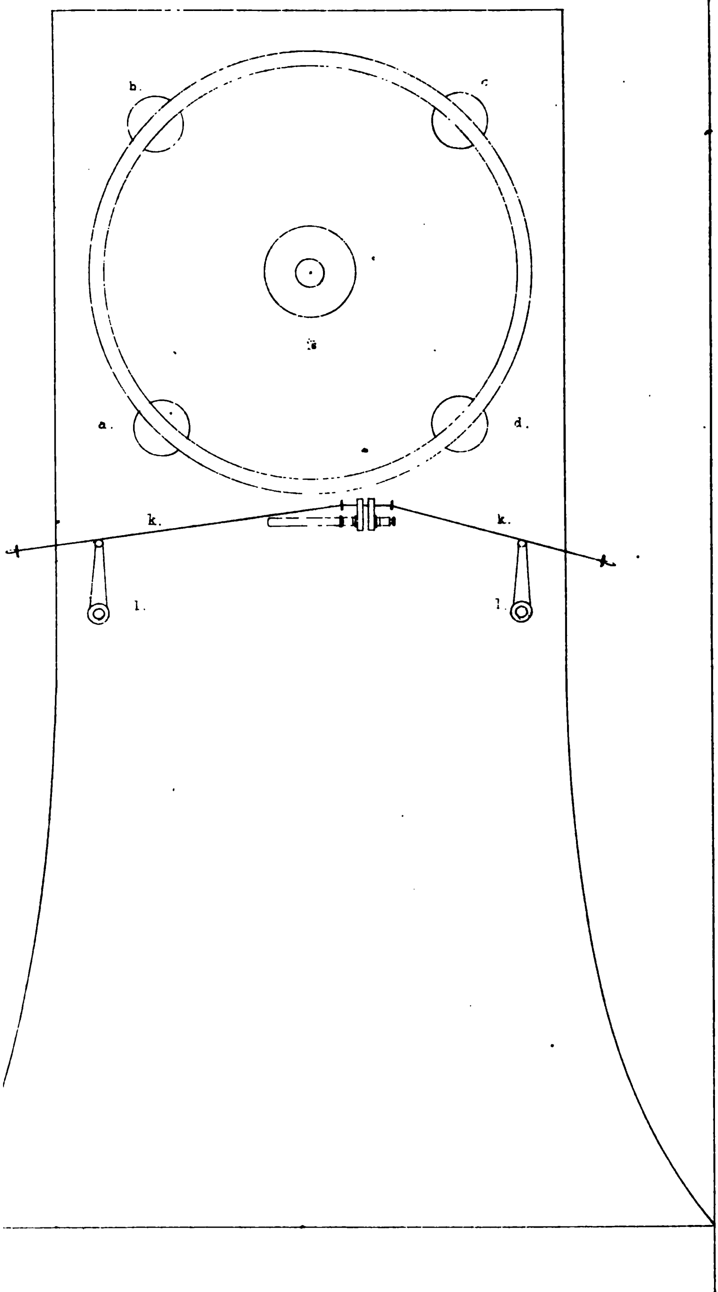

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Plate 6.

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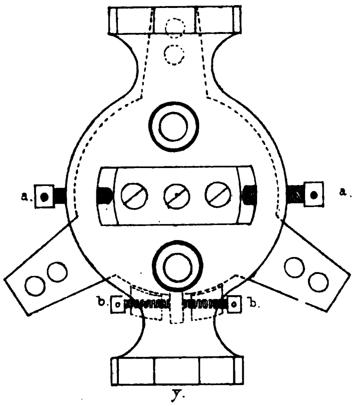

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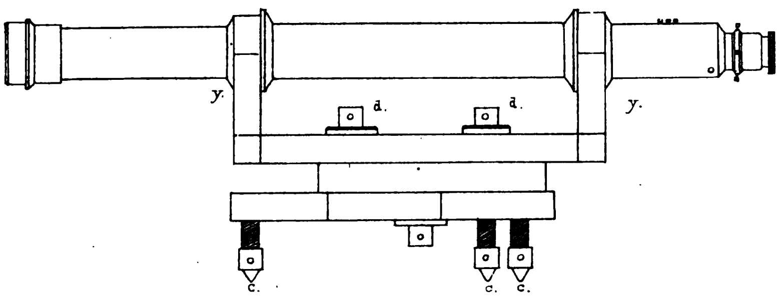

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of cast-iron and rests on an iron foundation, by means of the three steel screws *c, c, c,* having conical points. By turning these screws the telescope can be elevated or depressed at pleasure. They also serve to adjust the level of the instrument.

a, a, Screws for moving the frame carrying the telescope east or west.

b, b, Screws for adjusting in azimuth.

y, y, Y's in which the telescope rests.

d, d, Set screws for clamping, when the necessary adjustments have been made.

The collimator telescopes are of twenty-six inches focal length, and two inches clear aperture.

The portions resting in the Y pieces are cylindrical, and can be revolved so as to occupy any position.

The wires in the focus of the telescope are four in number, forming a square. They are attached to a plate which can be moved by four small screws on the outside of the tube.

When observations are to be made with them, the Olcott Meridian Circle is directed to the nadir, and the caps *q, q,* are taken off, which enables us to view the wires of one collimation by the other. They are brought in coincidence by making the necessary adjustments. The illumination of the wires is effected by means of gas burners placed behind the eye end. In day light, observations by the gas light can be dispensed with, but it is considered preferable to the sky light, since a better definition is secured.

The piers of the meridian circle, as well as those for the collimators, are covered with heavy woolen cloth and cased in wood; the better to protect them from sudden changes of temperature.

The meridian circle telescope is reversed by lifting it out of its Y's, by means of the reversing apparatus, fig. 1, and

Reversing Apparatus.

In making observations on the sun, the telescope is protected from the direct rays by means of a large screen, having an aperture in the center, placed in front of the instrument. Suitable mechanism is provided for giving the screen the desired elevation and angle of position.

For reflexion observations there is a separate iron track, laid about six inches below the surface of the floor, on which is placed an iron carriage, supporting a basin of mercury. This track is disconnected from the floor of the room, for the purpose of securing greater steadiness for the mercury surface.

In nadir and reflexion observations, the eye end of the telescope is reached by means of a pair of high wooden steps, mounted on wheels and running on the iron railway. When not in use, these steps are taken off the track and placed in one corner of the room. The ceiling of the room is entirely of wood, so there is no danger of loose plaster dropping upon the instrument.

Magnetic "make" circuit keys are attached to the north and south sides of the west pier, for making observations by the magnetic method. The clock for indicating the time of transit is set in the wall, nearly opposite the east pier. It is an ordinary one beating seconds, arranged with an electro-magnet placed near the center of oscillation, for putting it in sympathetic vibration with the standard sidereal clock. As observations by the eye and ear method are never made (as we prefer the chronographic for circumpolar stars), the magnetic mode of regulation is seldom used; since it is found to occasion less trouble to set the clock when necessary, than to keep the battery in order, besides the saving of battery elements.

The object glass is found to give a very clear definition, and is almost exclusively used with the full aperture.

The Transit Instrument.

This instrument was made by PISTOR & MARTINS of Berlin, and was mounted in the west wing, in the month of January, 1863.

The foundation on which the piers rest, is precisely the same as for the Olcott Meridian Circle. The piers are of Lockport limestone of the following dimensions: base 2 feet by 4 feet; height 7 feet 7½ inches; size at the top 1¾ feet —
by 2 feet. The weight of each pier is estimated at ne
four tons.

Plate III*a*, is a perspective view of the Transit, as
from the south-west, drawn on a scale of $\frac{1}{16}$ the full
In its principal features is similar to the Olcott Meri
Circle. The focal length of the telescope is 8 feet, and
objective is of $6\frac{3}{8}$ inches clear aperture. The defining p
of the object glass is excellent. The rays from a bright
are very short, and are symmetrically distributed ar
the center.

It is provided with two circles, which are two feet in d
eter, and are constructed on the plan best adapted to se
permanence of figure. The radii, or spokes, are in the
of a triangular prism, which gives the greatest strength
the least expenditure of metal.

As it was originally intended to attach the Declinom
apparatus to this instrument, one of the circles is undivi
and the other only divided to single degrees. If it sh
ever be deemed advisable to complete the divisions, we w
have in it an admirable meridian circle.

The supporting axis is 3 feet 5 inches in length, restin
steel wheels set in the arms *j*, *j*. The pivots are 2.5 inche
diameter. The Y-pieces, on which the pivots rest are slig
different from those of the meridian circle. They are n

PLATE II

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after the plan of a "slide-rest;" one is adjustable in azimuth and the other in level.

The finding circles *o*, *o*, are 10 inches in diameter, divided to 20 minutes and read by means of verniers to 30′ of arc. The transit wires are arranged in the same manner as for the meridian circle, with the exception that the interval between the groups is 6 seconds, and between the wires of the group 3 seconds of time. The eye piece has motion only in a horizontal direction. There is a single micrometer screw *s*, for giving motion to the vertical wire, used in the determination of collimation and level errors. The illumination of the wires in the focus is effected by the gas burners *v*, *v*, that designed for the illumination of the field entering by one pivot, and that for the threads by the other. The amount of the illumination can be regulated with the nicest precision, by means of the screw-heads *b*, *b*, near the eye end.

Explanation of Plate IIIa.

a, is a screw-head for giving horizontal motion to the eye piece.

s, is a screw-head for giving motion to the vertical micrometer wire.

b, *b*, are screw-heads for regulating the amount of illumination.

o, *o*, are the finding circles.

n, *n*, is the clamp apparatus.

m, is the hand rod for tightening the clamp on the axis.

h, is one of the brass arms for moving the telescope in zenith distance.

j, *j*, are the supporting arms, on which the axis rests.

i, *i*, are lead cylinders, enclosed in brass, for relieving the pivots of the greater part of the weight of the instrument.

v, *v*, are gas burners for illuminating the wires.

c, is a brass cup, for holding the lamp when making observations in the nadir.

t, *t*, is an iron railway, for the observing chair and reversing apparatus.

The telescope is reversed by placing it on an apparatus, precisely similar to that used for the meridian circle, fig. 1, and carrying it to the north until midway between the collimator and transit piers, when it is revolved through 180°, and placed in the Y's in a reversed position. The mode of reversal for both instruments is quite expeditious; since in the observation of Polaris we readily reverse between the groups, without the loss of a wire.

The spirit level is exactly like that used on the meridian circle. Advantage has been taken of this circumstance, in the employment of both levels on the same instrument for the better determination of the level error.

The Comet-seeker.

The Comet-seeker was made by ALVAN CLARK, of Boston, and is of 3 feet 6 inches focal length, and 4 inches clear aperture. The following is a perspective view of this instrument.

It is equatorially mounted, and is provided with right ascension and declination circles, of five inches in diameter, the former divided to two minutes, and read by a vernier to four seconds of time, the latter to half degrees and read by a vernier to minutes of arc.

It is arranged with the necessary adjusting screws for leveling and bringing the polar axis in the plane of the meridian. There are are two negative eye pieces, and one ring-micrometer. It is principally used in searching for new comets, and for finding those already discovered.

The Comet-seeker.

The Chronograph.

The invention of the magnetic method of recording transits opened a new era in the science of astronomy. It is probably one of the most important steps in improving instrumental astronomy, that has been made during the last half century.

Previous to the introduction of this method, various plans were adopted for noting the time of any phenomenon. The observer in recording the time of transit of a star across the wires of his telescope, listened to the beats of a clock, placed in a convenient position, and by counting the seconds and estimating the interval between two successive beats, determined the moment when the transit took place. This method, which required great skill in the estimation of the intervals of time elapsing, was, under the most favorable circumstances, but an approximation. By the new plan an inexperienced person will learn to record transits, in a single night, with greater precision than the most accomplished observer, after years of practice, by the old eye and ear method. Aside from the mere recording of the transits, the new method has other and more important advantages. In order to make the beats of the clock distinctly audible, it was necessary to apply a greater amount of weight, which acted very injuriously on the going, or rate of the clock. During high winds, or when there was noise about the building, the observer would sometimes, in the most critical observations, find it next to impossible to observe at all, and when he did succeed, there was often uncertainty regarding the integer number of seconds.

The "Journeyman Clock," constructed to give a loud beat, was used for a time, but the difficulty of causing it to keep a fixed rate for any considerable period, caused it soon to be abandoned. Sometimes two persons were employed to make

›servations; in such case, one watched the clock or ›meter, and the other, at the proper moment, called out "" or the like, when the assistant would note the time ›ed. One of the great sources of error by all of these ls, was in the uncertainty of the personal equation. ›antity was so great in some instances, as to amount ›le second of time. By the new method we get rid › all these sources of error; the observer has only to ›is attention to the moving object, and as it crosses press a key and the record is complete. The per›ation is not wholly eliminated, however, but is ›ithin much smaller limits, and is less liable to

›rm of Chronograph was the first ever constructed, inventor, Prof. MITCHEL, was among the first to › magnetic method, it will be desirable to give a ›is of the origin and application of electricity to › observation.

›ing facts have been derived from a report made › C. WALKER, in 1851; published in the 1st vol. › Harvard Observatory, and from other publica›uments:

Galvanic clock of WHEATSTONE, where the ›ade to make and break the electric circuit, by ›isk attached to the escapement wheel arbor.

Galvanic clock of STEINHEIL.

June 9th. First experiments for determining › the electric telegraph, made by Capt. CHARLES S. N. "The apparatus used this evening was constructed by JOSEPH SAXTON, Esq."

4th. 1846. Oct. 10th. Star signals exchanged between Washington and Philadelphia, by noting the signals.

5th. 1847. July 27th. Coincidence of beats of standard sidereal chronometers, tried between Philadelphia and Jersey City, by Mr. WALKER, Prof. E. O. KENDALL, and Prof. E. LOOMIS.

6th. 1848. July and Aug. Coincidence of star and clock signals exchanged between Harvard Observatory and New York, by Mr. WALKER, Prof. W. C. BOND, and Prof. E. LOOMIS. "During these experiments, Prof. BOND conceived the idea of using an automatic circuit interrupter; and one was ordered for the U. S. Coast Survey."

7th. 1848. Oct. 26th. Prof. O. M. MITCHEL, at the suggestion of Mr. WALKER, prepared a circuit interrupter which was attached to an ordinary eight day clock, and used it to graduate the running fillet of paper for several days.

"This method had been proposed by JOSEPH SAXTON, in 1846; but was not adopted, from apprehension of injury to the astronomical clock."

8th. 1848. Oct. 26th. "Dr. J. LOCKE having stated his objections to Mr. BOND'S contrivance of a circuit interrupter, was requested by Mr. WALKER, in behalf of the Coast Survey, to undertake experiments to obviate the supposed defects. These we know do not exist."

9th. 1848. Nov. 17th. Dr. J. LOCKE caused a clock to record its beats on a fillet of paper, as delivered by a Morse register.

10th. 1849. Jan. 19th. "First actual experiments of automatic imprint of star signals on a Morse register between

Cincinnati and Philadelphia, by Mr. WALKER, Dr. LOCKE and Prof. KENDALL."

11th. 1849. Jan. 23d. Longitudes of Cambridge, New York and Philadelphia determined by star transit signals. "The arrangements were under the charge of Mr. WALKER. The circuit breaking clock was prepared by Mr. WALKER, on Dr. LOCKE's plan, and located at Philadelphia."

"The same clock contained a tilt-hammer interrupter, for making signals by the teeth of the hour wheel every two minutes. This instrument was invented in the year 1847, by J. J. SPEED, Esq., President of the Telegraph Company, Detroit, Mich."

12th. "The detection of a delay in the transmission of the galvanic inducing wires, proportionate to the space traversed, was made by Mr. WALKER immediately after examining and comparing together the register of the four stations."

13th. 1849. April. Prof. MITCHEL constructed his revolving disk.

14th. 1849. July 20th. Mr. SAXTON completed his revolving cylinder.

15th. 1850. April 12th. Mr. W. C. BOND submitted a model of his revolving cylinder.

The following drawings will exhibit the chronographic mechanism in detail.

Fig. (1) is a vertical sectional view of the machinery, used for driving and regulating the chronographic disk.

Fig. (1.)

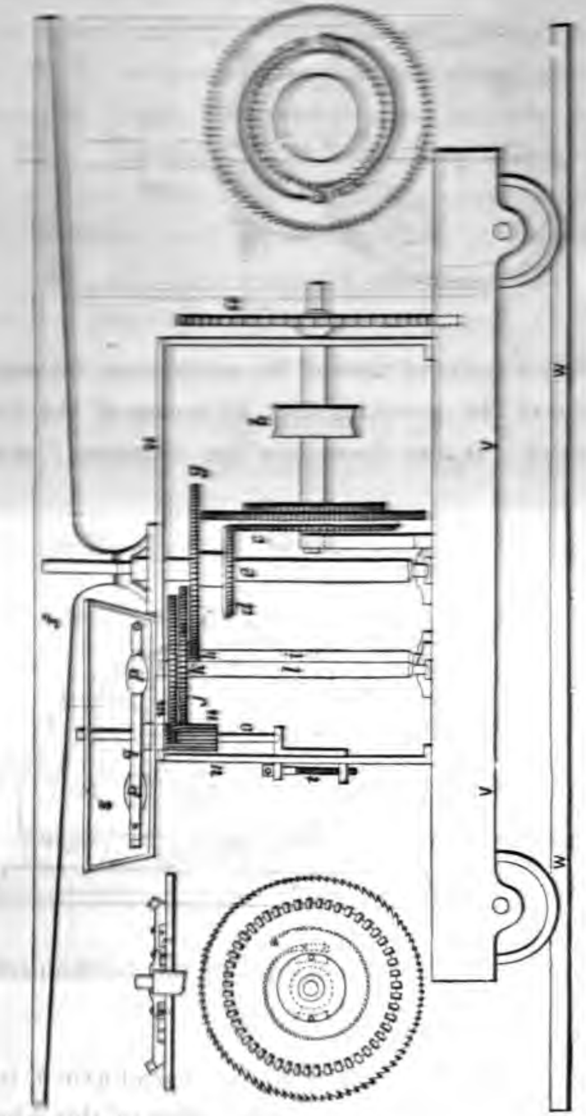


Fig. (2) is a horizontal sectional view of the same, both drawn to ⅛ the full size.

FIG. (2.)

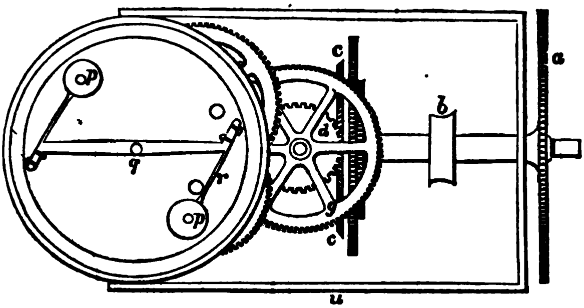
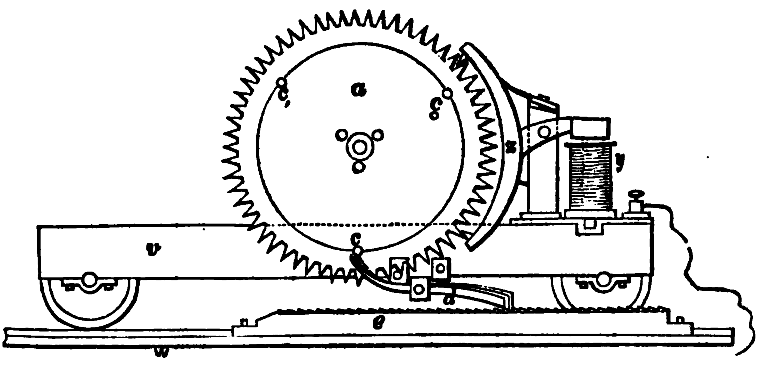


Fig. (3) is a sectional view of the mechanism, for regulating the motion of the revolving disk by means of the standard sidereal clock. It also shows how the "tripping" is accomplished.

FIG. (3.)



The following is the explanation of the mechanism. The letters are same on all the drawings:

a. 90-tooth wheel, attached to the barrel axle *b*, to which the driving weight is applied. The office of this wheel is to regulate the motion of the revolving disk, *f*, or rather to maintain a motion of stable equilibrium.

b. Barrel for the cord, to which the driving weight is attached.

c. Bevelled cog-wheel, carried by the barrel *b.*

d. Bevelled cog-wheel, gearing into *c*, and attached to the vertical shaft *e.*

e. Vertical shaft, supporting the revolving disk *f.*

g. Cog-wheel attached to the shaft *e*, and geared into the pinion *h.*

i. Vertical axle, to which is attached the pinion *h*, and the cog-wheel *j.*

j. Cog-wheel attached to the axle *i*, and geared into the pinion *k.*

l. Vertical axle, to which is attached the pinion *k*, and cog-wheel *m.*

m. Cog-wheel gearing into the pinion *n.*

o. Vertical axle to which is attached the pinion *n*, and supporting the Fraunhofer friction balls *p p.*

q, *q*. Brass arms, to which are attached the friction balls *p*, *p*, by means of the springs *r*, *r*.

s. Conical brass box, in which the friction balls *p*, *p* revolve. The balls *p*, *p*, in revolving rub against the inside surface of the conical box *s.*

t. Screw for raising or depressing the balls *p*, *p*. This screw serves to regulate the motion of the revolving disk.

u u. Brass box inclosing the mechanism.

v, *v*. Cast-iron frame for supporting the whole apparatus.

W, *W*. Iron railway track.

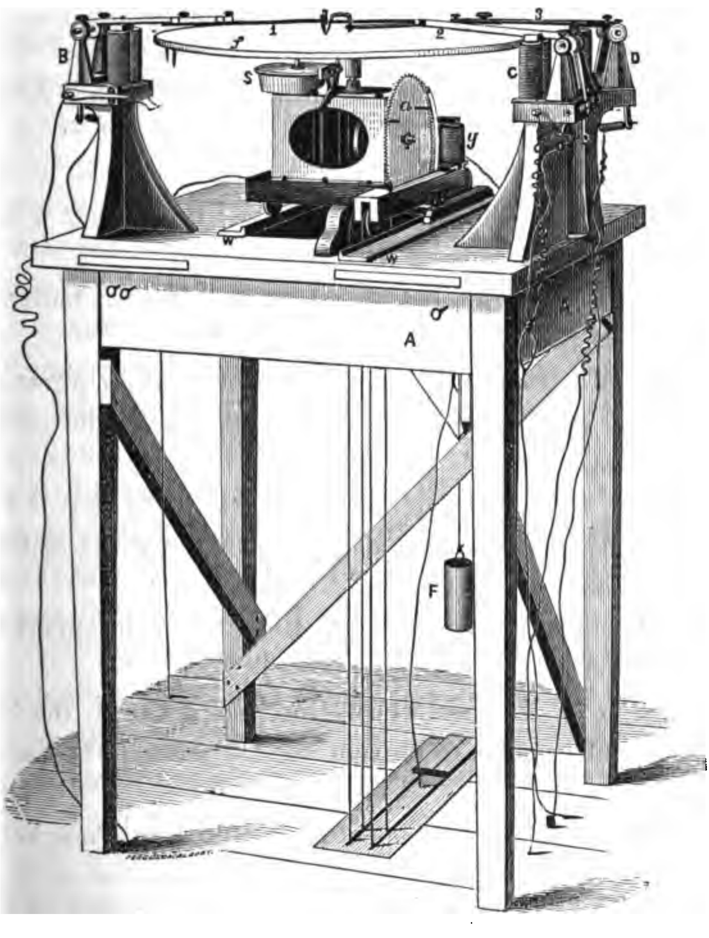
x, *x*. *Fig.* 2. Ratchet wheels inserted between the cog-wheel *c*, and barrel *b*, to prevent sudden jerks in the motion of the disk *f.*

z. *Fig.* 3. Escapement, operated by the electro-magnet *y*, serving to keep the motion of the disk in a state of stable eq[illegible]

The electro-magnet *y*, is operated by the standard sidereal clock, and "beats" once every two seconds. If the disk revolves too rapidly, the escapement holds it back, if too slowly, it is accelerated. When the motion is properly regulated by the screw *t*, the escapement has but little work to perform. It was found, that the Fraunhofer friction balls alone, would not give motion sufficiently uniform.

A perspective view of the Chronograph complete is seen in fig. (4).

FIG. (4).



A, A, is a stand on which rests the whole mechanism.

B, C, D, electro-magnets, which operate the recording pens (1), (2), (3).

The electro-magnets B, C, D, and the pens connected with them, are fixed to the stand A, A. The revolving disk *f*, and the machinery connected with it, is free to move on the railway track, *W, W*.

The disk *f*, on which the observations are recorded is 22 inches in diameter, and makes a complete revolution once every minute. At the end of every revolution, or between the fifty-ninth, and sixtieth second, as recorded by the standard sidereal clock, it moves back the 0.07 of an inch. This is accomplished by means of three small steel pins of different lengths inserted in the side of the escapement-wheel *a*, Fig. 3, at distances of 120° apart. These pins, marked c, c_{o}, $c_{,}$, successively elevate the steel dogs *d*, *d*, *d*, as shown in figure (3), detaching them from the ratchet *e*; when the disk is drawn back by means of the weight, F, the cord of which passes over a pulley attached to the stand, in the rear.

This motion of the mechanism we designate "tripping."

It is not important that the "trip" should take place between the fifty-ninth and sixtieth second, but is rather more convenient that this should be the case. If the disk is not started at the proper time to fulfil this condition, it is only necessary to mark the time when it does occur, by observing it through a complete revolution. In our every day work, we are not particular as regards the time of tripping.

The pens (1), (2), (3), are flexible metallic arms; and can be adjusted to make their record exactly in the center of the disk *f*. For this purpose they are made in two pieces; being held together by set screws. For one of the pens, we use a metallic point, for the other ordinary lead pencils.

The wires attached to the electro-magnet B, pass to the

battery, thence to the standard sidereal clock. Those attached to the electro-magnets C, D, pass through the battery, and thence are connected with the various observing instruments. The pen (2) is used for recording the Olcott Meridian Circle observations, and for comparison of the clocks. The pen (3) is used for recording the Transit observations, and those made with the Equatorial.

The wires are so arranged, however, that by simply turning a key, either of the two pens can be used with all the instruments.

The pen (1) operated by the electro-magnet B is called the "time" pen, and is used exclusively for recording the oscillations of the pendulum of the standard clock; its records being made once every two seconds. As we use the "make" circuit our records will be in the form of dots or punctures; since at every revolution, the disk "trips" or moves back, the "time pen" dots will be in concentric circles about the center, and straight lines or radii, reckoned from the center out. The recording pens (2), (3), are adjusted so that their dots fall between two of these concentric circles.

We employ two batteries, one for operating the time pen, and one for the recording pens. After trying batteries of various kinds, we finally adopted that of DANIELL, as being the most economical and best adapted to the wants of an observatory. Its greatest advantage, consists in being always ready, when we wish to make chronographic records. Under favorable circumstances, it will maintain sufficient power for two or three months without cleaning; it only being necessary to add a little water and sulphate of copper, every two or three weeks, to supply the necessary waste.

This mechanism is exceedingly simple, and is not liable to get out of order; since it will usually run a whole summer without changing the adjusting screw *t*. During the winter

season it does not perform as well, owing to the great change of temperature to which it is exposed; being located in the northwest corner of the transit room. It might perhaps be improved by causing the escapement *z z*, to regulate at shorter intervals, viz., every half second; or, what would be better still, apply a conical pendulum which should act continually.

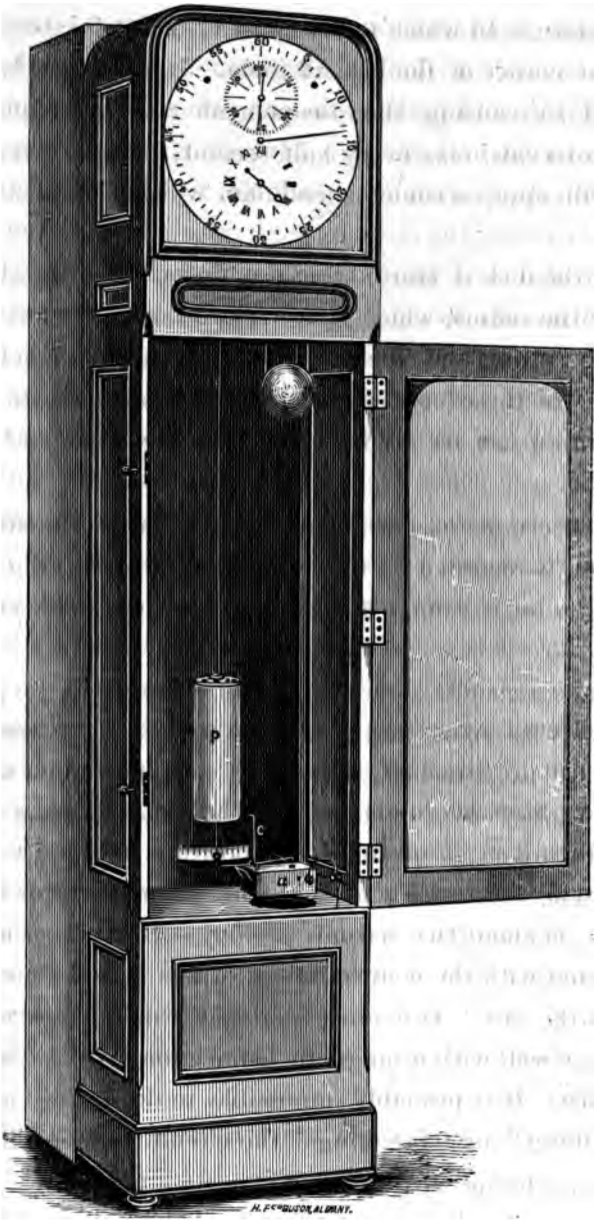
When the disk is started (we use for our records about 8 inches of the radius, which gives us two hours of right ascension), the zero of the clock is marked, as also the hour and minute. As these concentric circles are one minute apart, the other minutes are marked after the observations are complete.

Every alternate oscillation of the standard sidereal clock pendulum, is recorded on the chronograph, by causing a delicate wire cross, to plunge a platinum point in a small mercury cup.

This mechanism is shown in fig. (5), where P is the pendulum, *c* the wire cross, and *a* a block to which the cross and mercury cup are attached. The cross is supported on an axis, and is slightly over-balanced. When the magnetic connection is broken, it occupies the position as shown in the figure. The total effect of this connection, on the rate of the clock, is about two seconds per day. But after the clock is regulated with the connection on, it has but little variable effect on the rate. It is our experience, that a clock will not perform as well with a magnetic connection, as when allowed to run free. It is probably impossible to devise any method, for "making" or "breaking" the circuit, without, in some degree, interfering with the rate of a time keeper.

In the first experiments with magnetic connections, Prof. MITCHEL connected this cross with the pendulum by means of a delicate spider web. In this case, the cross was con-

FIG. (5.)



stantly acting on the pendulum, while with the present method the pendulum is disturbed only for 0.1 or 0.2 of a second, during a double oscillation. Both methods are equally good, with perhaps the exception, that the spider web is liable to be broken. We have also recently employed a solid connection on sidereal clock No. 2. The connection was made by causing the cross to press on a fine platinum spring. We have also used two platinum springs, but in neither case were the records so regular as with the mercury connection.

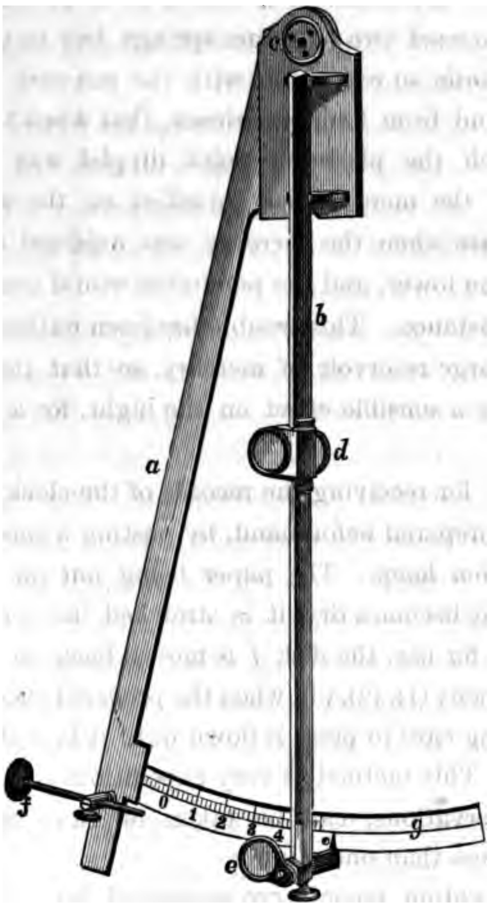
It was found from long experience, that when the mercury cup in which the platinum point dipped was small, the oxidation of the mercury had an effect on the rate of the clock; because when the mercury was oxidized the surface would become lower, and the pendulum would not meet with the same resistance. This trouble has been entirely removed by using a large reservoir of mercury, so that the oxidation will not have a sensible effect on the hight, for a whole year or more.

The sheets for receiving the records of the clock and observations are prepared beforehand, by pasting a sheet of paper over a wooden hoop. The paper being put on in a moist state, when it becomes dry, it is stretched like a drum head. When ready for use, the disk *f* is moved back, so as to stand clear of the pens (1), (2), (3), when the prepared sheet is placed over it, taking care to press it down until it lays smoothly on the disk *f*. This method is very expeditious; since a sheet holding observations, can be taken off, and replaced by another, in less than one minute.

The observation records are converted into numbers, by means of an angular micrometer. This instrument is shown in fig (6), where *a* and *b* are brass arms or radii free to move about the center *c*. To the arm *a*, is attached the arc *g*, which is divided to read hundredths of seconds when applied to the

observation disk. At *d* there is a magnifying glass, having two lines at right angles, marked on its under side. This glass is free to slide on the arm *b*. At *e*, there is a small eye glass for reading the divisions; it is not used, however, in our ordinary work. When we wish to measure up the observa-

FIG. (6.)



tions, the record sheet is taken off the Chronograph and placed on a disk inclined at an angle of 45°. This disk has a vertical pin in its center, which carries the angular micrometer, by passing it through the opening at *c*. The sheet having

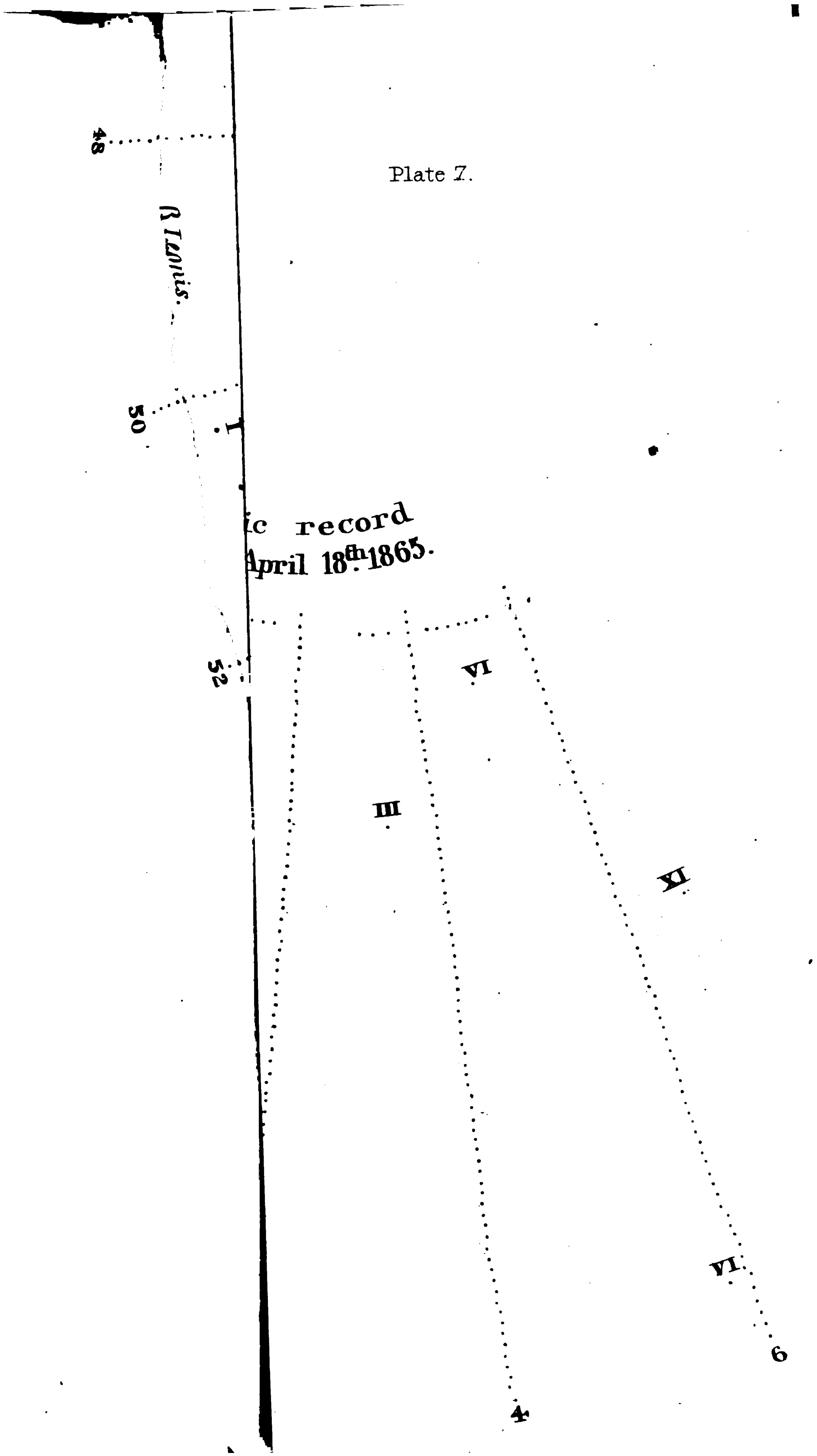
been marked, the index is moved, until its lines coincide with he circle of minutes, on which the records are found. The rm *b*, is then moved to the zero of the arc *g*; after which, the time" dot is bisected by the index *d*. The arm *a*, being in that position, *b* is moved out, until the index *d* bisects observation dot, when the fractions of a second are read n the arc. By means of a vernier at *e*, we can read one-rter of a hundredth of a second, but it is only for special that we employ the vernier.

this apparatus we measure up the observations very . An experienced person will measure up, to the udredth of a second, as fast as another can take down the adings; or in other words, a transit of 15 wires is usually easured up in one minute.

Plate 7, is a "*fac simile*" copy of a portion of a chronographic sheet, showing the manner in which the observations are recorded. We have before stated, that this sheet or disk is 22 inches in diameter, but only 8 inches of the radius is used for the record of the observations. The right lines or radii, are two seconds in time apart. Hence, having marked the zero of the clock on one of the lines, all the others are known; and they are accordingly marked 0, 2, 4, 6, 8 seconds, etc. The hour and minute are found marked on the line of 0 seconds, and since the concentric circles of dots are one minute apart, it is readily seen how all the others are known.

The 1st object recorded was the star *l* Leonis, and the 1st wire, which is always designated by two dots, was observed at $10^h\ 42^m\ 49^s.77$; the 2nd at $52^s.15$, and the 5th at $43^m\ 00^s.05$. The hour and minute are found on the line of 00 seconds. The 5th wire lies between the 42nd and 43rd minute, and as wer "time" dot is employed to determine the minute, ust be on the 43rd. The "trip" having occurred

Plate 7.



at the 40th second, the wires I, II, III, and IV are on the 42nd minute.

The integer seconds are read from the bottom of the sheet. The 1st wire is found between the 49th and 50th second; the fractional part being measured by the angular micrometer.

Near the bottom of the sheet is found the star β Leonis. The following is the record of the 1st six wires, I., 11^h 42^m $50^s.29$; II, $52.^s85$; III, $55^s.49$; IV, $58.^s04$; V, 43^m $00^s.61$; VI, $05^s.79$.

The examination of this sheet, readily shows how the records are converted into numbers. In our regular work, the number of the wire is not marked, only the name of the object.

The zero of the standard clock is recorded on the disk, by tapping with the key six times, immediately following the 0 seconds. The hour and minute is also recorded by tapping a certain number of times, immediately after the six dots are struck. On this sheet, the zero was recorded at 10^h 37^m 00^s. The 3 and 7 dots, immediately following the 6, indicate 37 minutes, and the single dot on the right, 10 hours.

In the reduction of our zone work in 1864, it occurred to me that much time and labor might be saved, provided we could at once read from our sheets the mean right ascension for the beginning of the year, or any other epoch. This was readily accomplished by a slight modification of the angular micrometer. The divided arc g, was increased to read a little more than 3 seconds, and the fine screw f was attached, as shown in fig. (6).

The nature and operation of this plan will be best understood by an example.

Reduction for Zone observed Nov. 16th, 1864, to 1863.0.

Clock error, from ι Piscium and γ Piscium, at 0h sid. time $= -16^s.31$; clock rate hourly $= -0^s.05$.

Sid. T.	Red. for Clock.	Red. for Wire.	Prec.	Red. to Mean Place.	Final Reduction.
0^h 0^m	$+16^s.31$	$+30^s.11$	$-3^s.07$	$-4^s.00$	$+39^s.35$
0 30	+16.33	+30.11	−3.07	−4.14	+39.23
1 00	+16.36	+30.11	−3.07	−4.27	+39.13
1 30	+16.38	+30.11	−3.07	−4.37	+39.05
2 0	+16.41	+30.11	−3.07	−4.46	+38.99

The column of final reductions, shows what quantities are to be applied to the record sheet, to reduce the stars to Mean place 1863.0.

Before proceeding to "measure up," a small table is formed, as a guide to the person who reads the record sheet. The following is a sample:

Sid. T.	Red.	Sid. T.	Red.
0^h 00^m	$+39^s.35$	0^h 30^m	$+39^s.23$
2	.34	33	.22
5	.33	36	.21
7	.32	39	.20
10	.31	42	.19
12	.30	45	.18
15	.29	48	.17
17	.28	51	.16
20	.27	54	.15
22	.26	57	.14
25	.25	1^h 00	$+39^s.13$
27	.24		

This table shows that at 0^h 00^m Sid. T, we must add $39^s.55$ to the disk reading, and this quantity must be uniformly diminished $0^s.01$, for every 2 or 3 minutes, so that for 1^h 00^m we add $39^s.13$.

The addition of the entire seconds is effected, by simply marking the disk 39 seconds more than the clock zero. The fractional increment $0^s.55$, is obtained by an adjustment of

the angular micrometer, by means of the screw *f*, so that $0^s.00$ on the disk, shall read $0^s.55$ on the arc or scale. The variation between $0^s.55$ and $0^s.13$, is accomplished by the same screw *f*, with which the zero of the vernier is shifted $0^s.01$ for every 2 or 3 minutes of right ascension, as may be requisite. In the above example, the zero needs to be changed at 2, 5, 7, 10, 12 minutes, etc.

The additional time required for measuring up with these adjustments, will not exceed 10 minutes for one hour of right ascension; while the saving is equivalent to the labor of one person in reduction, besides the increased accuracy of the results. In case the reduction to mean place is a negative quantity, it is readily changed to a positive by diminishing the disk reading one minute.

The Declinometer.

This instrument, as its name indicates, is used for the purpose of measuring the difference of declination between two objects.

In the year 1849, the late Prof. O. M. MITCHEL conceived the idea of measuring the distance between two stars, by magnifying by mechanical means the motion of the telescope in passing over the space which separated them.

In carrying out this conception, he attached an arm of six feet in length to the declination axis of the Cincinnati Equatorial. This arm carried an electro-magnet which was so connected with a light lever that whenever the electric current was driven through the magnet, it caused a metallic point at the lower extremity of the arm to make a minute dot on a strip of type-metal placed underneath. The distance of these dots from any fixed point was afterwards measured with a microscope magnifying about fifty diameters. Owing to the great labor in measuring up the work, and the confusion which would arise from having so many dots mixed together, particularly when many stars were observed having nearly the same declination, the method was soon abandoned.

About the year 1853 the subject was again taken up, when in the same manner an arm of seven feet in length was attached to the Equatorial (the telescope being clamped in the meridian). The lower end of this arm was connected with a light wooden lever moving horizontally on a vertical pivot; the centre of motion being about one inch from the extremity of the long arm, and eighteen inches from the reading point. The arc for reading the amount of motion was divided into spaces of ten seconds. After considerable trial, this method also was found impracticable—probably from

the fact that the motion was not sufficiently magnified, since one second on the scale would correspond to the seven-thousandths of an inch, a quantity too small to be easily measured.

He afterwards substituted in place of the lever a small telescope, moved in the same manner; but owing to some mechanical difficulties, this also was soon abandoned. After numerous experiments, he at length adopted the form of apparatus at present used in this Observatory.

The following is a description of its mechanism. Fig. 1 is a perspective view of this instrument as seen from the south-west.

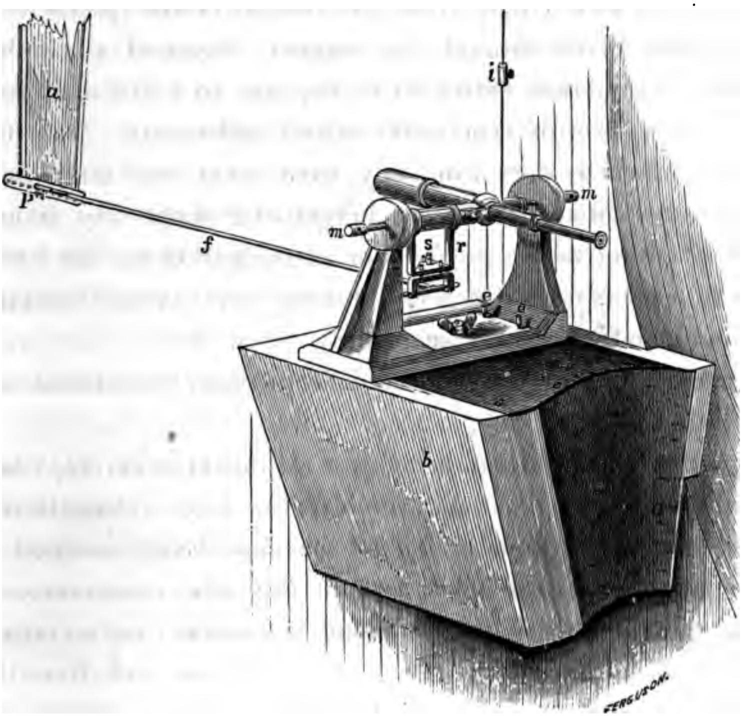


FIG. 1.

To the axis of the Olcott Meridian Circle is attached a metallic arm sixty inches in length, a portion of which (a) is seen in the drawing. The position of this instrument, with [ref]erence to the Meridian Circle, is shown in plate *Ia*, where [a i]s the long arm, t reading telescope, and p, p cylindrical pins. [Th]e lower end of this arm carries an arc, having for its radius [th]e length of the arm, sixty inches. Into this arm is screwed [a] number of cylindrical pins (p) one-eighth of an inch in [dia]meter, placed 30′ apart, at right angles to the arm, and [pa]rallel to the supporting axis of the telescope. These pins [hav]e a groove cut in the middle, of the form which would be [pr]oduced by placing the vertices of two cones together. At a distance of twenty-three inches from the centre pin, and in the same horizontal plane, a small telescope of six inches focal length, is mounted in knife-edge Y's; its supporting axis being parallel to that of the Meridian Circle. This telescope, which is shown in the figure, is supported on the oak block (b), ten inches square, bolted to the east pier of the Olcott Meridian Circle. To the top of this block is screwed an iron plate 0.5 of an inch in thickness, on which rests the stand holding the small telescope.

To the supporting axis of the small telescope is attached the arm (r), two inches in length, and by means of a joint the light rod (f) is connected with one of the pins at the lower end of the long arm (a). The short arm (r) is made in two portions, so that it can be lengthened or shortened at pleasure by means of screws seen at (s). The arm (r) can also be moved about the axis; being held in position by a set screw not shown in the drawing.

In order to avoid all play or loss of motion, the connecting rod (f) is attached to the reading telescope by means of a short axis with cylindrical holes in the ends, the axis being attached to the arm (r) by two screws having conical points.

The other end of the rod is connected with a pin at the lower end of the long arm (*a*) by means of an angular notch, similar to the letter V inverted.

It may be observed, however, that the connecting rod (*f*) is not essential, but is used merely for convenience, since the machinery would be simplified by connecting the reading telescope immediately with the long arm (*a*).

Now when the Meridian Circle is moved in zenith distance, angular motion is given to the small telescope by means of the long arm and connecting rod. The amount of this motion is read from a vertical scale divided into seconds of arc, fastened to the north collimator pier at a distance of fifteen feet from the centre of the reading telescope. It will, of course, be understood that we must have some object in the focus of the small telescope with which to compare the divisions of the scale. We use either a cross formed by the intersection of two spider's webs, or a single horizontal wire.

The scale comprises an arc of 33′. The length of 1′ at the centre of the scale is 1.5 inches, and the length of a second 0.025 inch, a quantity easily read by the small telescope. The second, in fact, can readily be divided into 4 equal parts; but ordinarily we read at a glance half seconds.

In case it is desired to observe a greater arc than 30′, the available extent of the scale, the end of the connecting rod (*f*) is raised and attached to a different pin; the interval between the pins having previously been determined.

The Adjustments of the Apparatus.

All the adjustments for making the small telescope read minutes and seconds on any part of the arc, are accomplished by changing the position of the scale, by changing the length of the short arm (*r*), by changing the angle which the arm (*r*) makes with the collimation axis, and by moving the whole

scope nearer to or farther from the scale. It is not neces-
r to enter into the details of these adjustments, as every
ly understand how they are accomplished. When
adj d, it will remain so. Any change, from tempera-
r other causes, will only have the same effect as the
rdinary microscopes. This will of course be deter-
e time of observation. To make the apparatus
it is necessary to use a double notch for hooking
distance between the notches may com-
are of any other value, provided it be

rors incident to this Apparatus.

irces of error incident to this form of mechanism are ew and easily determined. When we consider the apparatus in a theoretical point of view, it might at first sight seem impossible to make any combination of machinery which would, with certainty, indicate a motion of 1″ of arc. One might suppose that there would easily be that amount of play or lost motion in the joints. That there is some lost motion, no one will deny; but the main question is, will there be sufficient to seriously impair an observation, and what is the limit of this source of error? The amount of this error is easily determined from direct comparison with the 8 microscopes of the Olcott Meridian Circle, as well as from the apparatus used alone. Our method of determining this is to direct the telescope to one of the collimators, and measure the interval between the opposite angles of a square formed by the intersection of four wires placed in the focus of the collimator telescope. When the collimator is revolved so that the angles are east and west, and above and below, the interval between the angles is about 42″. The following readings will give a fair sample of the performance of this

apparatus. The bisections were made with the tangent screw for giving slow motion to the meridian circle in zenith distance; beginning with the lower angle and moving over the whole space and some distance beyond.

	Telescope moved to increase the zenith distance.		*Telescope moved to diminish the zenith distance.*	
	Upper Angle.	Lower Angle.	Upper Angle.	Lower Angle.
	11′ 10″.0	10′ 28″.5	11′ 11″.0	10′ 28″.7
	11 .5	28 .3	11 .1	29 .0
	10 .5	28 .0	10 .7	28 .0
	11 .0	28 .3	10 .6	28 .3
	10 .2	28 .0	10 .7	28 .5
Mean	11′ 10″.64	10′ 28″.22	11′ 10″.82	10′ 28″.50

Zenith dist. diminishing — Zenith dist. increasing = + .18″
" " " " " " = + .28″
Mean = + .23″

the loss of motion in bisecting, from moving the telescope in opposite directions.

From this it follows that the error due to this apparatus from loss of motion in the joints, is no more than in the best micrometer screw.

Hence we conclude that the distance between two stars can be as accurately determined as with the filar micrometer or meridian circle, using any number of microscopes. A positive advantage may, indeed, be justly claimed for the use of this apparatus; for when, with a meridian circle, only one bisection of each object can be made, at least ten bisections and readings for each, during the time of transit, can be made with the declinometer, thereby eliminating the error of bisection arising from perturbations of the atmosphere or inaccurate observation.

The Errors due to Change of Temperature.

First. Let us consider the effect of change of temperature on the long arm (a), which is made of iron and is sixty inches in length. The errors due to this will be of two kinds. First, the change of the value of the divisions on the scale, which will be $0''.0004$ on $1'$ for a change of 1° of temperature. Second, the change of position in the reading telescope, resulting from the change of angle made by the connecting rod (f) with the long arm (a). Computation gives for this a change of $0''.02$ for a variation of 1° of temperature. Hence we may, from theory alone, conclude that the change in the length of the long arm, from the effect of temperature, will not introduce an appreciable error.

Second. The effect of temperature on the short arm (r), and the supporting stand (which is made of cast iron), the height of the stand being 4.2 inches. If the temperature be supposed to increase, the effect will be to raise the telescope and make it read higher on the scale. This would be constant for all parts of the scale. Computation indicates, for 1° of temperature, a change in position of $0''.001$.

The short arm (r) will affect the reading in two directions: First, that due to the change of runs, which is equal to $0''.02$ for 1°; second, that due to change of position, which is equal to $0''.02$ for 1°. Hence we may regard the changes in this portion of the apparatus as inappreciable.

Third. Effect of Temperature on the Connecting Rod (f).

During the summer of 1862, in our experimental zone work with this apparatus, it was found, on comparing two zones together, extending over an hour of right ascension, that at times there was a variable difference between the

zones depending on the time; that is, if at the beginning of the zones the difference was made equal to zero, at the end it would have increased in some cases to 2″ of arc. This fact led me to make a theoretical investigation of the effect of temperature on all portions of the apparatus.

During these observations a brass tube, twenty-three inches in length, was used as a connecting rod. The change on the scale for a brass rod, was found by computation to be ±0″.90 for 1°. This at once gave an explanation of the apparent anomaly. It was then very desirable to use a connecting rod which would be the least affected by temperature, and yet retain its figure. After various substances were tried, a glase tube was finally adopted, as being permanent in its figure and not so greatly affected by temperature. Perhaps some other substance would be preferable. It would, however, be an easy matter to construct a rod of two metals, which would maintain a uniform length in all temperatures; and this we propose doing.

Computation gives for glass 1° ± 0″.38. The correctness of this is fully demonstrated by direct experiment. On a number of days the apparatus was attached to the Olcott Meridian Circle, which was securely clamped; and upon varying the temperature, by opening and closing the room, we obtained the following results. Temperature constant for 1° assumed equal to ± 0″.40.

1862.	Sid. T.	Temperature.	Scale reading.	Scale reading reduced to a uniform temperature of 40°
Nov. 22.	1h 45m	38°.2	15′ 14″.3	15′ 13″.58
23.	12 45	39 .0	14 .0	13 .60
23.	16 30	40 .1	13 .4	13 .44
23.	16 45	35 .0	15 .3	13 .30
23.	16 50	34 .0	15 .7	13 .30
23.	19 30	39 .1	13 .4	13 .04

1863.	Sid. T.	Temperature.	Scale reading.	Scale reading reduced to a uniform temperature of 40°
Feb. 28.	22h 30m	39°.0	15′ 00″.0	14′ 59″.60
28.	1 30	37 .0	00 .9	59 .70
Mar. 4.	1 45	24 .0	12 09 .1	12 02 .70
5.	21 15	32 .0	04 .3	01 .10
5.	22 15	18 .0	11 .6	02 .80

From these observations the temperature constant for the whole apparatus, is found to be + 0″.44. They also indicate that the temperature constant is very uniform; and that the apparatus is as stable for any length of time as the reading microscopes of the Circle.

Under ordinary circumstances, the changes of temperature of the observing room, during the passage of a zone of one hour in length, will not amount to more than 2°; and since direct comparisons with the Meridian Circle are made at the beginning and end of the zone, the effect of temperature is at once determined, independent of the thermometer readings.

We here append a few readings made during the process of our work.

1863. Date.	Sid. T.	Temp.	Scale.	Mean four Microscopes.
June 17.	15h 00m	62°.0	0′ 00″	+ 42° 40′ 05″.75
17.	16 50	60 .0	0 00	+ 42 40 04 .90
29.	15 30	73 .0	0 00	+ 42 40 03 .48
29.	17 30	70 .0	0 00	+ 42 40 02 .75
Oct. 17.	22 50	62 .0	0 00	+ 42 38 45 .35
17.	23 50	60 .0	0 00	+ 42 38 43 .60

In these readings, the small telescope was compared with four microscopes of the Olcott Meridian Circle, giving the zero of the declinometer scale, as referred to the zero of the Circle, at the beginning and end of the zone. By applying the adopted temperature constant, and reducing the two scale

readings to the same standard, we would have the following errors on the position of the zones, possibly due to this apparatus.

June 17.	± 0″.02
29.	± 0 .23
Oct. 17.	± 0 .47

These results show that the mean temperature constant would not introduce at any time an error which would sensibly affect the observations.

It is unnecessary to speak farther of the stability of the apparatus; experience has shown that it is as stable as the Meridian Circle itself, which is all that can be desired.

It now remains to determine the effect of temperature on the scale itself. A difference of 1° would change the length of the scale (30′) only 0″.02; so that the error arising from this source is also inappreciable.

The illumination of the scale is effected by causing a gas light to move on an iron arc, nearly in front of the scale. The position of this light is regulated by the assistant who reads the scale, by means of a cord running over two pulleys, to the end of which is attached a weight which is placed near the reading telescope. To shut off, as much as possible, the light from the observing room, a box has been constructed, with a narrow slit in the side fronting the scale, which encloses the whole apparatus. The proximity of the gas light, has no sensible effect on the scale, as has been fully determined by careful comparisons with the microscopes of the Olcott Meridian Circle.

In using this apparatus in zone work, the Olcott Meridian Circle is first set in zenith distance on the centre of the zone to be observed, and securely clamped. The long arm (*a*) is then clamped to the east side of the supporting axis. The small telescope being placed in its Y's, the connecting rod is

pped on the centre pin. To bring the long arm exactly in
, plane of motion of the collimation axis of the reading
escope, we have recently added a bar holding a horizontal
ew, which rests against the cube of the Meridian Circle
he long arm. By means of this screw we adjust for any
ition from this plane, the object being to prevent lateral
on the connecting rod. All this having been done,
scope is then set for the edge of the zone, at present
The Meridian Circle is now moved in zenith
so that it is directed to this point in the heavens,
' 00″ declination. The assistant reads his scale,
nnas the reading for this point 0′ 30″. In order, there-
ke the scale read 0′ 00″ declination, it is necessary
the angle made by the long arm with the telescope
; or, which is the same, to change the angle of the read-
g telescope. The easiest way to accomplish this, is to
change the length of the connecting rod. To effect this adjustment, we have recently attached a fine cut screw in the end of the rod, for giving motion to the notch resting on the pins. This is not shown in the drawing. While the assistant looks through the telescope at the scale, the observer turns this screw until the division 0′ 00″ is bisected by the wire of the reading telescope. The width of the zone to be observed is then regulated by the mechanism shown in plate 3. In case the apparatus is used with an instrument having no microscopes or means of measuring zenith distance accurately, a star preceding the zone, whose place was accurately known, could be used. We adopt the latter method on observing our zone the second time.

When this apparatus is ready, a ruled sheet is placed on
charting machine; and having set it to give mean right
ension and declination for the beginning of the year, we
repared not only to observe accurately the transits and

declinations of the stars, but at the same time to produce a Star Chart, with the magnitudes and positions recorded. For the exact transit or right ascension, the stars are, by the same pressure of the key which makes the record on the chart, recorded on the Chronograph, from which the records are read to the one-hundreth of a second of time.

With this apparatus two persons can observe 300 stars in one hour. The average number found in our zones of the year 1863, including all stars up to, and a few of, the 14th magnitude, is 150 per hour. Our aim is not to observe a great many stars, but to take all stars fairly visible in the portion of the heavens under observation.

The complete reduction of the zone work by this method, comprises the following determinations: *First*, for declinations, the zero of the scale. This may be determined in two ways, namely, by comparing the scale with the Circle at the beginning and end of the zone, or by using a few standard stars in the zone, whose places have been well determined by many observations. The latter plan is preferred as giving the best results, since in this case the error of nadir of the Meridian Circle is eliminated.

Having determined the zero point for any time as the beginning of the zone, it is necessary to correct for the following:

1st. Runs of the scale, depending on the declination.
2nd. Differential refraction, depending on the declination.
3rd. Reduction to mean place, depending on the right ascension.
4th. Variable refraction, depending on the time or right ascension.
5th. Temperature correction, depending on the time, or right ascension.

The following will show the quantities combined:

[Scale reading + zero-point + (runs + differential refraction) + (reduction to mean place + variable refraction + temperature correction)] = Mean declination.

For all practical purposes, the apparatus may be so adjusted that the runs will eliminate differential refraction.

Second. For the right ascension we have the following reductions:

1st. Clock error, at the beginning of the zone, found either on the night of observation from the Transit of Nautical Almanac stars, or, which is preferred, by using the standard stars of the zone.

2nd. Reduction of wire (constant).

3rd. Reduction to mean place, depending on the right ascension.

4th. Clock rate, depending on the time or right ascension.

The clock rate is nearly always eliminated.

We have then for the complete reduction in right ascension:

Time of transit + (clock error + reduction of wire) + (reduction to mean place + clock rate).

This may be put under another form, namely:

(Clock error + reduction of wire + reduction to mean place at the beginning of the zone) + (variation of reduction + clock rate.)

This change will show more clearly how the mean right ascension is measured directly from the chronograph records, without any numerical computation for separate results.

The observed Transit needs to be corrected by a constant quantity, x and a variable quantity, $\triangle x$ depending on the time or right ascension. The method adopted for applying these quantities *mechanically*, will be found under the description of the chronograph, illustrated by an example.

Machine for Cataloguing and Charting Stars.

The progress of instrumental astronomy has been so rapid during the last half century, not only in the perfecting of the older instruments, [illegible] in the invention of new methods of [illegible] present time more can be accom-

plished in one year than could formerly have been done in five.

In the year 1848 the application of electricity to the recording of astronomical observations was first suggested. This happily conceived idea soon resulted in the construction of Chronographs by various persons, by which the instant of transit of a star was accurately recorded in a legible and permanent manner. Success in the recording of one ordinate of a star's position, would naturally suggest the possibility of fixing the other by the same agency. But with the exception of some experiments made by the late Prof. O. M. MITCHEL, for the recording of declinations by electricity, this subject, so far as I know, has not been undertaken by any other astronomer.

In the formation of catalogues of zone stars, astronomers have almost invariably used the telescope in a fixed position, and by means of a diaphragm or scale placed in the focus, determined the time of transit and difference of declination. In our method the telescope is moved in zenith distance, the amount of motion giving us the difference of declination.

This method of observing the difference of declination between two objects, by magnifying by mechanical means the angular motion of the telescope, is due to the late Prof. O. M. MITCHEL, who first put it in practical operation in the year 1849; the apparatus used for this purpose being called the Declinometer.

Perhaps nothing is more desirable at the present time than accurate ecliptic charts of all stars down to the 14th magnitude. We already have the charts of Chacornac, Argelander and others, which are of great value in the search for Asteroids; but were these charts filled out, as it were, with stars of a higher order of magnitude, it would greatly enhance thei[illegible]or this purpose.

All standard charts that have heretofore been constructed, have been made by laying down the positions of the stars, as given by a catalogue previously formed. This, of course, is an extremely difficult and tedious task. It seemed to me that much time and labor might be saved, provided we could make an accurate map at the same time that we observed for exact positions. This result we have succeeded in accomplishing by means of easy and simple mechanism, a description of which will be given in this connection.

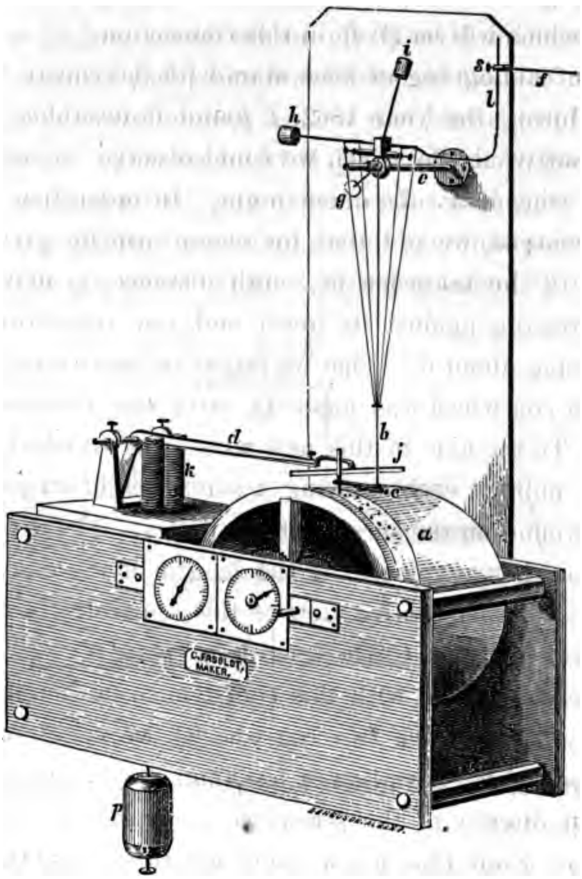
In the cataloguing of zone stars with the Olcott Meridian Circle, during the year 1862, I found it desirable to have some contrivance by which we could observe the same zone, star for star, on a subsequent night. In order that we may be understood, we add that the clamp arm for giving slow motion to the telescope in zenith distance, is moved by a screw pressing against its lower end, one revolution of the screw being about 6′. That we might get more rapid motion, an extra cog-wheel was made to drive one fastened to the screw. To the axis of this new wheel was attached two cylindrical pulleys, each carrying a small weight suspended by a cord wound on the surface of the pulley. The width of the zone was then regulated by the length of the end left free to move. A perspective view of this apparatus is shown in the Olcott Meridian Circle description, plate 3.

It was found that with this contrivance (although we had the play between the two cog-wheels), we could follow the same zone with a deviation of less than 5″. Were the pulleys attached directly to the screw, we knew the error would be still less. From this fact we were led to surmise that difference of declination could easily be read to the tenth of a minute, from a screw head used for giving slow motion to the telescope.

In thinking on this subject, I conjectured that if a cylinder

ere attached to this screw, and a pen made to move over with a uniform velocity in the direction of its length, we uld readily record both Right Ascension and Declination, , in other words, make a map of the stars observed. Owing the inconvenience in attaching such an apparatus to our strument, the plan was not put in execution.

FIG. 1.



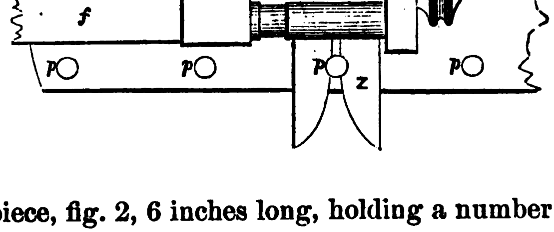
We will now proceed to give a description of the Charting achine. Fig. 1 is a perspective of the machine, as seen om the southeast.

This apparatus is firmly fastened to the south side of the west pier. It is connected with the clamp arm of the Telescope by means of the horizontal rod (*f*), 40 inches length.

A clock work mechanism, having a half second's pendulum (*p*), carries the cylinder (*a*), 6 inches in length and 10 inches in diameter; which revolves from west to east, and makes a complete revolution every hour.

Directly over the cylinder is mounted, on a horizontal axis, the compound lever (*b*, *l*); to the lower end of which, by means of a short horizontal arm and joint, a hollow cylindrical steel pen is held in a vertical position over the axis. The lower part of this lever (*b*), is 18 inches long; the upper part (*l*) is 6 inches long. In order to magnify as much as possible the angular motion of the clamp arm, we attach to it a strong iron bar, 25 inches in length. At the lower end of this bar is

FIG. 2.



a cross piece, fig. 2, 6 inches long, holding a number of cylindrical pins (*p*).

Each of these pins has a notch cut in the middle, of the form which would result from placing the vertices of two cones together. By this arrangement, there can be no loss of motion; besides, it affords great facility in changing the rod from one pin to another.

The rod (*f*) is connected with the clamp arm by dropping the notch (*z*), fig. 2, on one of the pins.

The other end of the rod is attached to the lever (*l*), fig. 1. A sectional view of the mechanism for this purpose is seen in

FIG. 3.

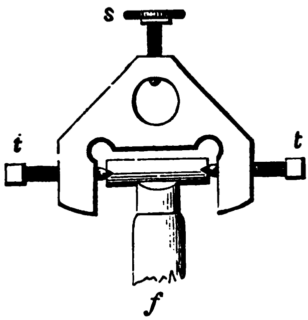
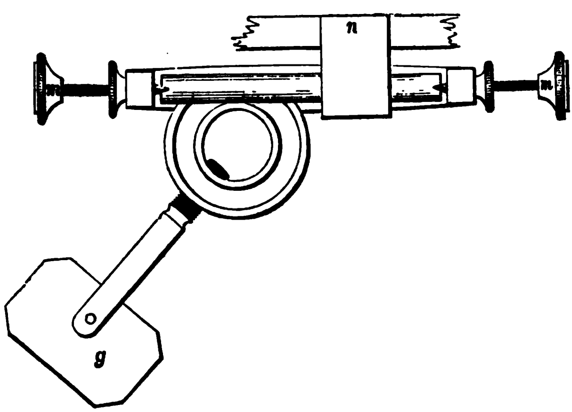


fig. 3; (*t*, *t*), being two screws having conical points, (*s*) a set screw for clamping to (*l*).

FIG. 4.



The arm carrying the steel pen shown at (*c*), fig. 1, is attached to the lever (*b*), by an arrangement precisely similar to that seen in fig. 3, the steel pen being held above the paper by a flat spring attached directly to the lever (*b*).

The lever (*b*) is supported on the horizontal post (*e*), fig. 1; *g* is a set screw for clamping to any part of the post (*e*); *h* and *i* are weights for counterpoising the lever in any position.

The supporting axis of *b* is seen in fig 4, where *m*, *m*, are two screws having conical points. By this arrangement, we avoid all loss of motion, and have but very little friction.

In fig. 1, *k* is an electro-magnet operating the arm (*d*), at the end of which, and parallel to the axis of the cylinder, is attached the cross piece *j*.

The dials seen in fig. 1 indicate minutes and seconds.

Now, when the Telescope is moved in zenith distance, motion is given to the pencil so that it moves over the cylinder in the direction of its axis. Whenever we wish to make a record, a key is pressed which closes the circuit through the electro-magnet, and a blow is struck on the pencil arm, so that a small dot is made on the sheet of paper covering the cylinder.

It remains now to show how the magnitudes are recorded on the chart. Various plans were suggested, and I finally decided to represent the magnitudes by different colors. For this purpose we use prepared paper, known as duplicating impression paper.

If a strip of this paper be laid over a sheet of ordinary writing paper, and a pen be drawn over it, a colored impression will be left on the paper. In the same manner, if a blow be struck with a blunt point, a colored dot will be the result. Now, if at the time of observation an assistant should introduce a strip of this paper under the steel pen, when the record was made, we would have a colored impression denoting the magnitude. So, it is readily seen, should the assistant introduce these strips of paper as required, we would produce a chart with the magnitudes all recorded. But obviously this method would require an extra assistant, and would consequently be an unnecessary waste of time. It is, then, very

desirable that the introduction of these strips should be in the power of the observer himself.

Various kinds of apparatus might be employed for this purpose, but what we need is simplicity and certainty. We at first placed our strips on a belt running over two rollers, so that by giving motion to these rollers, any strip of colored paper could be brought under the recording pen. This plan answered the purpose, but was somewhat inconvenient to put our sheets on the cylinder. We therefore removed it, and placed the strips of paper on an arm moving about a vertical axis, and by means of a cord, attached to a lever connected with the rod used for giving slow motion to the telescope in zenith distance, the observer was enabled to bring any desired color under the pen, and this, too, without removing his eye from the telescope.

This part of the apparatus is not shown in the drawing, but being so simple the reader will not fail to understand it. So far we have used only five different colors, but the number can be increased to any extent. These colors indicate 9, 10, 11, 12 and 13th magnitudes. When stars of the 14th magnitude are observed, no color is introduced, and we have for our record merely a puncture on our zone sheet. When stars below the 9th magnitude are observed, (and there are but few, generally three or four in a night), a note is made by the assistant, and they are recorded on the chronograph by striking a certain number of dots to indicate the magnitude.

As fast as the stars enter the field of the Telescope, they are brought to the intersection of a horizontal and vertical wire, when, the circuit being closed, the record is made. In this way, the positions of the stars in the heavens are transferred to the surface of the cylinder, so that when our observations are finished, we have a perfect "*fac simile*" copy of the zone of stars observed.

This apparatus we believe is the first which has been constructed to record accurately, by mechanical means, the right ascension and declination at the same instant, or in other words, to make a chart of the stars observed.

When the dot is made on the cylinder, a record is also made on the working Chronograph, which gives us the time to the hundreth part of a second. For the exact declination, an assistant reads the Declinometer scale to the five-tenths of a second.

Therefore, when our zone is observed, we have not only a complete catalogue of the exact positions of the stars, but also a perfect map of the heavens.

In case we do not read our declinometer scale, we can determine the declination from the chart, within one-tenth of a minute of arc. The precision with which this machine will map stars is all that could be desired; since if two charts of the same zone, made on different nights, be placed one over the other, the stars will be superimposed so that the eye can detect no difference.

By means of movable adjustments we can set the machine (having our sheet ruled for Right Ascension and Declination), so that it will give the position of the zone, at the beginning of the year, without sensible error. For adjusting in Right Ascension, the cylinder can be moved about its axis, being held in position by a friction block. For the declination, we lengthen or shorten the rod (f), by means of the screw (x), fig. 2. The scale for declination can be varied at pleasure, by changing the position of the connecting rod (f), on the lever l, fig. 1. This apparatus can be adapted to any Telescope either transit or equatorial; neither does its use interfere with the ordinary work for exact positions.

In the observation of Asteroids on the meridian, a great deal of time is wasted, especially when the error of the Ephe-

meris is considerable. And even when the error is only 2′ or 3′ in declination, in certain portions of the heavens, it is almost impossible to find the body with a meridian instrument. This apparatus affords great facility in finding these bodies, when we have an approximate Ephemeris; since it is only necessary to observe, on two nights, a short zone of five minutes in Right Ascension and 10 minutes in Declination. The comparison of these two charts will at once show which is the planet, provided it is included within those limits; when, the Ephemeris being corrected, it can be observed on the meridian in the usual way. This has been thoroughly tested in finding the old Asteroids, where the error of the Ephemeris has been considerable.

In our ordinary work, as we observe all stars visible, the limit being 13-14 magnitude, it is usually impracticable to observe a zone of greater width than 10′ or 12′, and within these limits it is not unusual to find more than 200 stars in one hour of right ascension.

In case we wish to extend our observations over more than one hour of right ascension, we loosen the clamp screw (*g*), fig. 1, and slide the whole apparatus carrying the pencil, on the post (*e*); the end of the connecting rod (*f*) being raised up and dropped on another pin. These changes can all be made in less than one minute.

From the comparison of the positions given by the chart with those found by the declinometer, the mean error on the chart position is found to be less than the one-tenth of a minute of arc. In the prosecution of zone work, these charts have been found of great value in correcting doubtful observations, without the necessity of re-observing the zone. In case a wrong minute is entered by the assistant charged with taking down the declinometer readings and other remarks, on comparing with the chart we readily make the necessary

corrections. The use of this apparatus in nowise interferes with our work for exact positions, since we have found the mean error of our observations to be the same whether the stars were charted or not.

Our work during three years' experience has demonstrated the practical utility of the apparatus. If for any purpose we desire a map of the stars in a certain portion of the heavens, we can make one in a few minutes, which by any other method would require hours. In the region of the milky way, where small stars are very numerous, we have charted them at the rate of 480 per hour, and at the same time observed every star in the zone above the 14th magnitude.

Every one will at once see that a series of charts, even in the condition in which they are taken from the cylinder, will be of great value to the observatory in which they are made. For, after being numbered and filed, they become so many maps, although the width does not exceed 10 minutes of arc. But obviously they can be made of greater service, with but little additional labor, by transferring contiguous zones to one sheet. This is easily accomplished by merely pricking through the paper with a series of points, which shall at once indicate the magnitudes.

In case we wish to search for Asteroids, we believe much labor can be saved, and equal if not greater facility afforded in their discovery. For, suppose we have already completed a series of charts for one hour of right ascension, and one degree declination, it is only necessary to observe and map the same zone, or any portion of it; when it is readily seen, should there be any Asteroid in that region which was not there when the former charts were made, it will at once be detected. The objection may be offered, that with the ordinary meridian instruments, we do not have optical power sufficient to detect these faint bodies. Granting this to be

the case, it does not affect the principle of the method, for we can use the apparatus with an equatorial of any size. In the latter case, we would clamp the Telescope securely in the meridian, and, attaching an arm to the declination axis, at once connect our apparatus in the same manner as with the transit. Slow motion in declination can now be given to the Telescope with the tangent screw, and the width of the zone limited by employing any mechanism suitable to the instrument. These minor details, of course, will be arranged by the observer, as circumstances require.

Automatic Registering and Printing Barometer.

The science of Meteorology is as yet in its infancy. Universally interesting as its phenomena have ever been, and powerfully affecting the most important relations of society, it is but recently that the subject has engaged the systematic and combined effort requisite for its development, since its laws are still regarded as the most recondite problem in Physics. The first thing to be done is of course the collection of facts, and much is now being done in England and on the continent in this direction. The chief obstacle, hitherto, has been in the imperfection of the methods of observation. The results, in order to be of value as data from which to construct a science, should present a *continuous* record of the phenomena during a considerable period of time, and taken at as many different stations as possible. By the ordinary method of personal observation, this is well nigh impracticable. It would demand at every station the services of several observers, at great expense, and their results could only at best be more or less of an approach to what is desired. To obtain this, the only alternative is to substitute some mechanical means for the labor of personal observation; in short, to make the instrument record

its own changes. If this can be done in a single instance, it can be done continuously.

The only method by which this has been hitherto attempted with success has been by the application of photography. This, though a very considerable advance, and probably all that could be desired in respect of continuity and accuracy of the record, is liable perhaps to the objection that it is too complicated a process for general use. If we consider the skill requisite in the preparation of the paper, the delicacy of manipulation involved by the apparatus, and the labor of interpreting the results, as compared with the average capacity and means of the great number of observers desired and likely to volunteer or be employed for such a purpose, it would seem that a simpler process is both desirable and necessary. This it has been my intention to furnish, and with what success remains for time and experience to determine. The importance of the subject will justify me perhaps in presenting some account of the new method.

The problem to be solved, was to cause any meteorological instrument, by means of suitable mechanism, simply and effectually to record its own changes. The instrument selected for experiment was the barometer. When any delicate instrument is made to record its own changes by mechanical means, the chief difficulty is that of getting sufficient power for the mechanism attached to make a distinct and continuous record, without taking a perceptible amount of force from the instrument itself, and thereby vitiating the results. The use of electricity naturally suggested itself as the best means of overcoming this obstacle. This agency has not as yet been made economical or certain as a motor, but is chiefly valuable in controlling power obtained through some other means. By it, as may be seen in its application to clock work, and in the telegraph, the

ents of one machine may be reproduced in another o greater expenditure of force than is requisite for al contact. In the cases cited, however, the motion reproduced is sensibly uniform and in the same direc- For the solution of our problem, a mechanism is ded that shall repeat the changes of the original in form, whether the motion be uniform or variable, for- or reverse.

feasibility of this plan was discussed with my friend THOMAS SIMONS as early as the year 1862, and some were then taken to apply it to the thermometer. I here express my acknowledgments to Mr. SIMONS for able suggestions in the construction of the present line. Various plans were considered for effecting the rical contact with the fluctuating medium which is the of this method. It was at first proposed to do this at surface of the mercury in a siphon barometer, by means a platinum wire which should be carried continually tard the mercury surface by suitable mechanism, and on ching the surface, a galvanic current would be formed ich should operate by an electro-magnet on the mechanism as to reverse the motion of the wire and break the circuit. is would be immediately restored by the normal move- nt of the mechanism, and thus the point of contact would kept oscillating *at* the surface continually. The consump- n of battery power by this plan would have been consider- le, and it was thought the oxidization of the mercury by electric circuit would in time be appreciable. It was refore concluded to make the connection outside of the rometer tube, by means of a float resting upon the mer- y column. By this plan there is no demand of action m the battery until some change takes place in the

barometer, and a considerable saving of battery elements is effected.

Attention was then given to determining the degree of delicacy with which changes of the mercury surface could be represented by this process. It was found by experiment that a motion of less than .0005 of an inch was readily shown, a quantity far within the limits of reading of a first class standard barometer.

The next step was to devise the proper mechanism for repeating the motion thus transferred, and recording it in some legible form. A finely cut screw was considered as best adapted to measure such minute intervals of space. To this screw a forward or reverse motion was given by a double system of clock work, each operated by an electro-magnet in connection with the float, and raising or lowering the screw by intervals corresponding with the changes indicated in the mercury column.

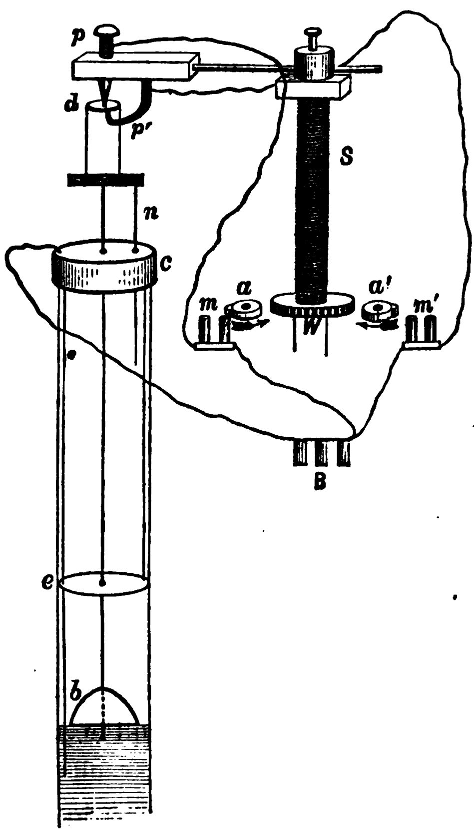
In respect to the permanent record of results, it was decided not only to attempt the production of a linear diagram or curve of atmospheric pressure, as an interesting method of presenting the recorded changes to the eye, but to avoid the tedium and uncertainty of measuring up such results, by producing at the same time a printed record of such variation, to any extent deemed advisable.

Having thus endeavored to give some conception of the design and principal features of this method, I will proceed to explain more fully the details of its execution as at present arranged.

In order to make any self-recording machine of this kind practicable, we need to attend to two points. First, to reduce the consumption of electricity to the smallest possible amount consistent with certainty in the results; and secondly, to secure the greatest amount of useful work with the mini-

mum of labor. We at once decided to adopt the "make" circuit; for so long as there is no motion, there will be no consumption of battery elements. The battery which we have adopted for recording transits is essentially that of Daniell; sulphate of copper being the exciting agent. A battery of this kind will maintain sufficient power for chronographic records for two or three months, without being cleaned; it being only necessary to add a little sulphate of copper and water from time to time, to supply the necessary waste. The only power demanded of the electro-magnets is the unlocking of the mechanism, which is driven by weight power.

FIG. 1.



In fig. 1, we have a sectional view of the lower leg of the siphon, showing the principle on which this method is based. It may be necessary to remark, however, that the electro-magnets and battery do not occupy these positions in reality, but are placed here for convenience of illustration.

Let B = battery.

" m, m' = electro-magnets.

" a, a' = wheels having one tooth, and revolving in the direction of the arrows.

S = screw supporting the arm, carrying two wires p and p', tipped with platinum.

d = platinum disk carried by the float b.

The two wires p, p', are respectively above and below the centre of the disk d.

W = wheel with 40 teeth in which is inserted the screw S.

n = a small steel wire passing through the brass cup c, to prevent the disk d from revolving.

e = an ivory disk inserted in the tube, to prevent the float b from rubbing against the sides of the tube.

Now suppose the mercury should rise in the short leg of the siphon, as represented in the figure. The float b will be raised, and cause the platinum disk d to come in contact with the point of the platinum wire p, closing the circuit through the electro-magnet m; the armature of which being attracted, unlocks the clock-work, and allows the wheel a to make a complete revolution. By this means the wheel W is advanced one tooth, which raises the screw S the $\frac{1}{2000}$ of an inch, and consequently carries the point p that distance away from the disk d.

As long as the mercury rises, the magnet m will be operated, and the platinum point p will be kept the $\frac{1}{2000}$ of an inch above the disk d.

If, on the contrary, the mercury falls in the siphon, the

under side of the platinum disk *d* will be brought in contact with the point of the wire *p′*, thereby closing the circuit through the magnet *m′*; the armature of which allows the one tooth wheel *a′* to make a complete revolution, thereby causing the screw *S* to be depressed the $\frac{1}{2000}$ of an inch, carrying, of course, the platinum point *p′* with it.

It will now be readily seen how the platinum disk *d*, carried by the float *b*, may always be maintained midway between the two points *p* and *p′*, and distant a little less than the $\frac{1}{1000}$ of an inch from each.

The barometer is of the siphon form; the inside diameter of the portions near the surface of the mercury is nearly one inch. The upper and lower portions were made from the same glass tube, the two being connected by a tube of smaller diameter. The experiments and observations, so far, indicate that there is no appreciable difference in the size of the two legs of the siphon.

The float *b* is of ivory; the form, a paraboloid of revolution. The under side of this float is very slightly concave. The diameter is one-eighth of an inch less than the inside diameter of the tube, so that there is no friction between the sides of the float and glass. The platinum disk *d* is supported by a steel wire passing through a brass cap *c* fitted on the top of the tube, and an ivory disk *e* inserted at a distance of 2½ inches above the float *b*. The ivory disk is connected with the brass cap by means of two wires, so that it can readily be removed. A light steel wire *n* passes through a hole in the cap, for the purpose of preventing the disk *d* from revolving. This is made sufficiently free to prevent any friction.

The disk *d* is made of brass one-half an inch in diameter, and is covered on both sides with platinum plates.

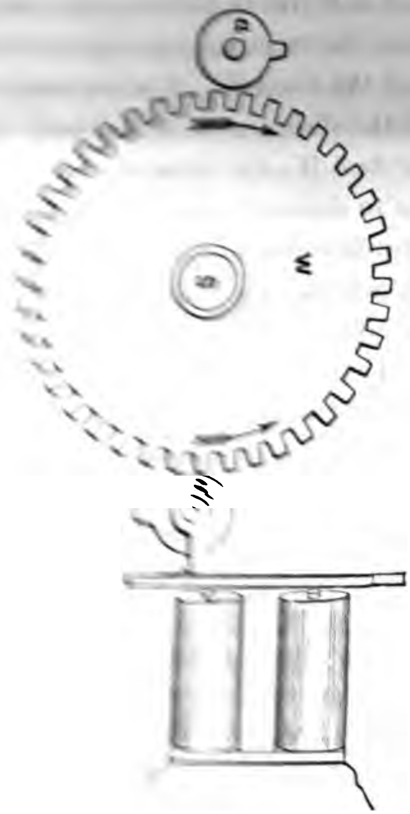
The platinum wire *p* is attached to a fine screw, for adjust-

ing the distance of the points p and p' from the surface of t
disk d.

These wires p and p' are, of course insulated by bei
attached to an ivory block, as shown in the figure. The wi
from these points are led to the top of the screw S, wh
they are fastened to an ivory block, after which they are c
nected with the electro-magnets m, m'.

A platinum wire is inserted in the side of the barom
tube, and passes down in the mercury on the side of
float, h. This wire is also connected with one pole
the battery.

Fig. 2.



The principle employed for giving motion to the screw *S*, which follows the fluctuations of the mercurial column, has been taken from the stop-work long used on clocks. The barrel of a clock on which the cord is wound usually has a one-tooth wheel on its axis; and at every revolution of the barrel, a cog-wheel is made to advance one tooth. This cog-wheel is, of course, always detached from the barrel tooth wheel, except when in the act of advancing the tooth. In fig. 2, we have a vertical view of a portion of the mechanism, showing the method of communicating motion to the screw *S*. The one-tooth wheels, *a*, *a′*, when at rest, occupy the positions as shown in the drawing; and being detached from the cog-wheel *W*, it is free to move in either direction. The screw *S*, which is shown in fig. 1, is raised or depressed by the revolution of the wheel *W*. The one-tooth wheels *a* and *a′*, moving in the direction of the arrows, give opposite motions to the wheel *W*; the office of *a* being to elevate the screw, and of *a′* to depress it, corresponding to the fall and rise of the mercurial column.

The mechanism for giving motion to the wheels *a* and *a′* is ordinary clock work, each being directly acted on by the barrel wheel, which is driven by a weight. One revolution of the barrel corresponds to twelve of the wheels *a* and *a′*. The axles, to which are attached *a*, *a′*, carry another wheel having a single half-tooth, as shown in the drawing, fig. 2, which, resting against a little projection on the armature of the magnet, holds the wheel in the position as shown in the figure.

In order that the wheels *a* and *a′* may not revolve with too great rapidity, a train of clock work is connected, consisting of two additional axles, a fan being attached to the latter, by means of which the motion can be regulated to any desirable velocity. Three axles would undoubtedly be sufficient,

the barrel axle, the axles *a*, *a'*, and an additional one for the fan. We adopted the present form, because we happened to have a couple of clock movements at hand, and used them just as they were.

In our first experiments, it was found, when the points *p*, *p'* were adjusted very close to the surfaces of the disk *d*, the oscillations of the barometer were liable to cause both wheels *a*, *a'* to revolve at the same time; and by this means, should their cogs arrive at the circumference of *W* together, the machine would become blocked.

This was easily remedied by introducing a circuit "breaker" on one of the wheels *a*, *a'*. As soon as the wheel *a* begins to move, the circuit is broken, and remains so until it comes to rest again; so that in case they should both start at the same instant, the cog of *a'* being in advance, it would make its revolution and come to rest, because the circuit would be interrupted until *a* should come to rest also. Since the circuit interrupter was attached, there has been no difficulty from this cause.

Fig. 3 is a perspective view of the apparatus as it is when in operation. The frame work for supporting the barometer tube and other mechanism is of black walnut two inches thick, which is firmly fastened to the east wall of the west transit room. This wall is built of brick, and is two feet thick, so that the whole apparatus occupies a very firm position.

Having given a general idea of the mechanism for causing the screw *S* to follow the motions of the barometrical column, we will show how the curve of pressure is recorded, as well as the printed results.

The wheel *W*, fig. 2, which receives the impulses, has 40 teeth; and the screw *S*, having 50 threads to the inch, one tooth of the wheel *W* corresponds to the $\frac{1}{2000}$ of an inch

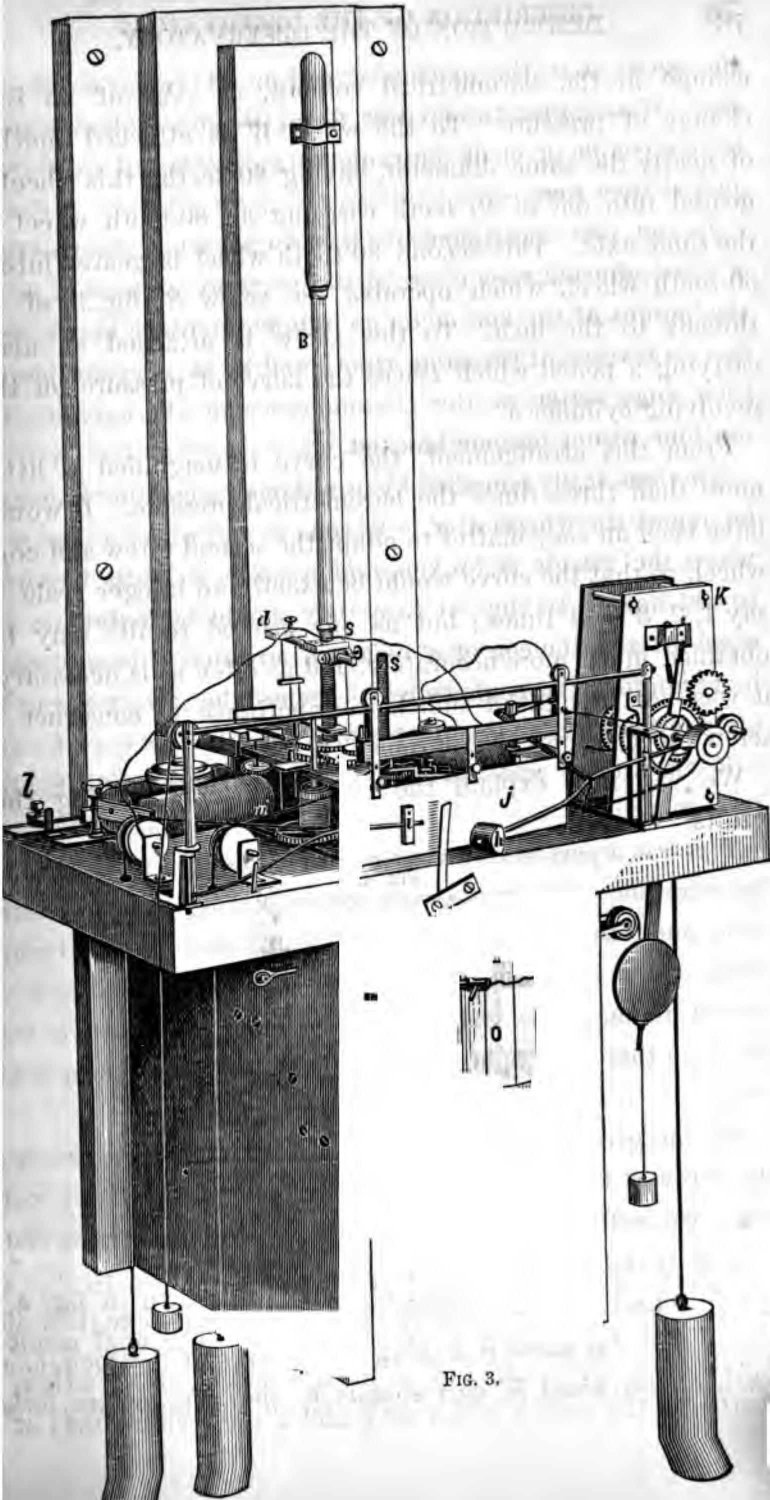


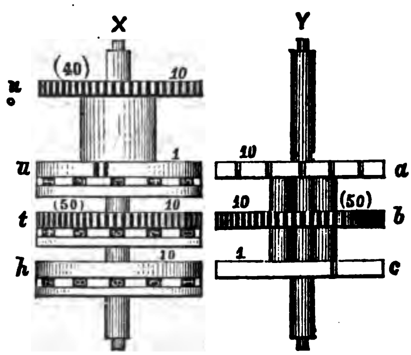
FIG. 3.

change in the barometrical column, or $\frac{1}{1000}$ of an inch change of pressure. To the wheel *W* is attached another of nearly the same diameter, having 80 teeth; this wheel is geared into one of 40 teeth carrying an 80-tooth wheel on the same axle. This second 80-tooth wheel is geared into a 50-tooth wheel, which operates the screw *S'*, fig. 3, of 26 threads to the inch. To this screw is attached an arm, carrying a pencil which traces the curve of pressure on the revolving cylinder *o*.

From this arrangement, the curve is magnified a little more than three times the barometrical pressure. It would have been an easy matter to adapt the second screw and cog-wheel, so that the curve would be exactly an integer scale — say 1, 2, 3 or 4 times; but as our printed results may be obtained much more accurately, and as often as is necessary, it was not thought of sufficient importance to construct a screw especially for this purpose.

We will now explain the mechanism for printing the results.

FIG. 4.



A sectional view of the combination is shown in fig. 4, where x and y are two vertical steel axles. The final result expressed in thousandths of an inch, is found on the axle x, where u is the units wheel, t tens, and h the hundredths; or

where the thousandths of an inch is the unit of measure, u will represent thousandths, t hundredths, and h tenths of an inch.

The wheel u_o may be supposed to have ten teeth, and is connected with u, so that they move together. If motion be given to u_o, so that it move one tooth at each impulse, each tooth will represent the $\frac{1}{1000}$ of an inch; and ten impulses, or a whole revolution, will represent the $\frac{1}{100}$ of an inch. The wheel u has one tooth, and the wheel a on the axle y has ten teeth. Now when u has made a complete revolution, it will have advanced a one tooth or one-tenth of a revolution; consequently the wheel a will always express the hundredths.

In order to transfer the motion of a to the axle x we fasten to a the wheel b, having ten teeth; and by gearing this in the wheel t, having ten teeth also, we transfer the motion of a to t, hence we have the thousandths and hundredths expressed on the wheels u and t.

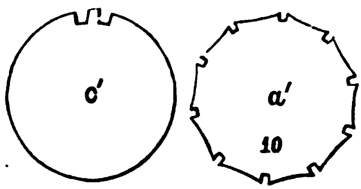
But let us go a step further, and see how we get our tenths. The wheels a, b, we have shown, indicate the hundredths: we therefore attach to them another wheel c, having one tooth. Let the wheel h of ten teeth be placed opposite. Now when the axle x, carrying the wheels a, b, c, has made one complete revolution corresponding to one tenth, the wheel h will have advanced one tooth; consequently the tenths will be represented on the wheel h.

It is of course understood that the wheels u, t, h, are separate, and free to move about the axis x. By repeating this combination, we can employ any number of figures we choose.

The wheels u, h, a and c, are made after the plan employed in the stop-work in a chronometer. In fig. 5, a' and c' indicate this form of gearing. It is seen that the teeth of one

wheel are cut in the arc of a circle, with the radius equal to that of the wheel into which it gears. This arrangement prevents any motion, except it be communicated by the units wheel. The whole mechanism is therefore locked together, and it is just as impossible for it to get out of order as it is for ordinary clock gearing.

Fig. 5.



The chief merit of this combination is, that it will carry for ten either forwards or backwards. This principle is necessary in any meteorological printing instrument. We need no extra apparatus for bringing the type in line, since if the mechanism is well constructed, it will always arrange itself. When once set it will remain so, for no change can be made without ungearing the machine.

We use ordinary type which are set in separate disks, being afterwards screwed fast to *u*, *t*, and *h*. In case a type is accidentally damaged or broken, another can be inserted in a few minutes. Steel type would undoubtedly be the best, as being more durable and less liable to damage. We should add, that the wheels *t* and *b* have each 50 teeth; five teeth being moved at one impulse.

The printed results are received on the strip of paper *j*, moved by the clock work *k*, fig. 3, which at the same time regulates the revolving cylinder *o*, on which is traced the curve of pressure. This same clock raises a small hammer *h*, by means of a screw or spiral on the minute wheel arbor, which at every revolution is allowed to strike the small cushion *i*, by that means leaving the impression of the type

on the strip of paper. In order to secure greater distinctness in the printed results, without employing much power to make the impression, a strip of duplicating impression paper is inserted between the type and ordinary sheet of white paper.

We are not limited in our printing to hourly records, but they can be obtained as often as is desirable, by supplying the additional power required to raise the hammer. The clock for moving the printed slip and cylinder is an ordinary half-seconds pendulum, which we happened to have at hand. It was not thought necessary to print the integer number of inches, nor the time; for the paper slip has the time already printed on the side, so that when the record of the day is completed, it is only necessary to add the date and integer inches.

One great advantage in the use of this instrument consists in the ease with which it may be manipulated. All the adjustments are simple and easily accomplished. Any person could learn, in a few days at most, to keep it in running order, and make any adjustments, should it become necessary from accident or other causes. No chemicals are needed, except the sulphate of copper for the battery, which may readily be procured in any town or village. Every part of the action is visible to the eye of the observer, so that in case any part gets out of order, it will readily be seen.

The screw *S*, on which the accuracy of the results will in a great measure depend, is, as before remarked, 50 threads to the inch, and was cut by Mr. CHARLES FASOLDT; and it is found to be a very perfect one. And I will here add that the whole mechanism was built in his shop, under my direction and supervision.

The best form and arrangement of the float can only be determined by experiment. In our original barometer tube,

which was 0.4 in. diameter, we inserted an ivory float which nearly fitted the tube. The upper end of the wire for supporting the platinum disk *d*, was connected with the arm carrying the platinum points. As this was the first trial of the new method, for a number of consecutive days, we append the results. The instrument was allowed to run from April 24th to 30th, without being disturbed. It was set with the standard barometer (Fastré), at 4 P. M., April 24th, 1865.

Date.		Temperature. Centigrade.	Standard Barometer reduced to 0 deg. Cent.	Printing Barometer reduced to 0 deg. Cent.	Difference.
April 24,	4h.	8.5°	29.947 in.	29.947 in.	+ 0.000 in.
" 25,	22	10.0	29.934	29.929	+ 0.005
" 26,	2½	13.0	29.789	29.784	+ 0.005
" 27,	21½	13.0	29.862	29.859	+ 0.003
" 30,	0	12.0	29.755	29.750	+ 0.005

During this period the barometer reached a maximum of 30.114, and a minimum of 29.435.

On the 30th, the machine was taken down to modify the printing apparatus.

A comparison of these results show that even with inferior and comparatively rough apparatus, the individual results are equal to a reading obtained from the best standard barometer. At this time the registering barometer was not compensated for temperature; the reductions being made from a short table computed for this purpose.

Numerous experiments have been made to test the stability of the float and magnetic connections. It will hardly be necessary to give the results in detail. In case there was no friction of any kind, the float ought always to assume the same position for the same height of the mercurial column. The following is the test we have applied. The electrical contact being broken by the key *l*, fig. 3, the screw *S* was turned so as to force the float into the mercury 0.010 of an

inch; after which, the current was established, and the float was allowed to take up a position of equilibrium. The same thing was repeated, by turning the screw in the opposite direction and lifting up the float. From many trials, it was found that there was rarely a difference of 0.002 of an inch, and usually less than 0.001 of an inch, from the original position. The same test was applied for larger disturbances, viz. 0.020 or 0.030 inches with nearly similar results. This is not a fair test, however, since these conditions are never realized in practice. From all our experiments so far, we see no reason why the machine should change its zero any appreciable amount, during a whole year or greater length of time.

The following extracts from our record book will best illustrate the stability of the mechanism.

July 4th. The machine was "blocked" for 6 hours. During this time the barometer rose 0.070 of an inch. After the float assumed its position of equilibrium, the zero of the machine, by comparison with the standard, was found unchanged.

July 20th. The float was screwed up and down 0.200 of an inch to see if there was any friction. After assuming its position of equilibrium, the zero was found unchanged.

Aug. 17th. Float taken out of the barometer tube to put in a heavier platinum wire. The zero was changed 0.005 of an inch; mostly due to the larger wire displacing a greater amount of mercury.

The daily comparison of the printed records, for the months of June, July and August, 1865, with the readings obtained from the standard barometer (Fastré), gave for the mean error of a single result ± 0.0035 in. This determination was based on the hypothesis, that the error of reading the standard barometer was zero; which we know is not the case.

The following is a *fac simile* copy of the record as printed by the machine. The numbers on the left hand are the hours from noon of the 11th to noon of the 12th. The remaining figures are the barometrical heights expressed in thousandths of inches.

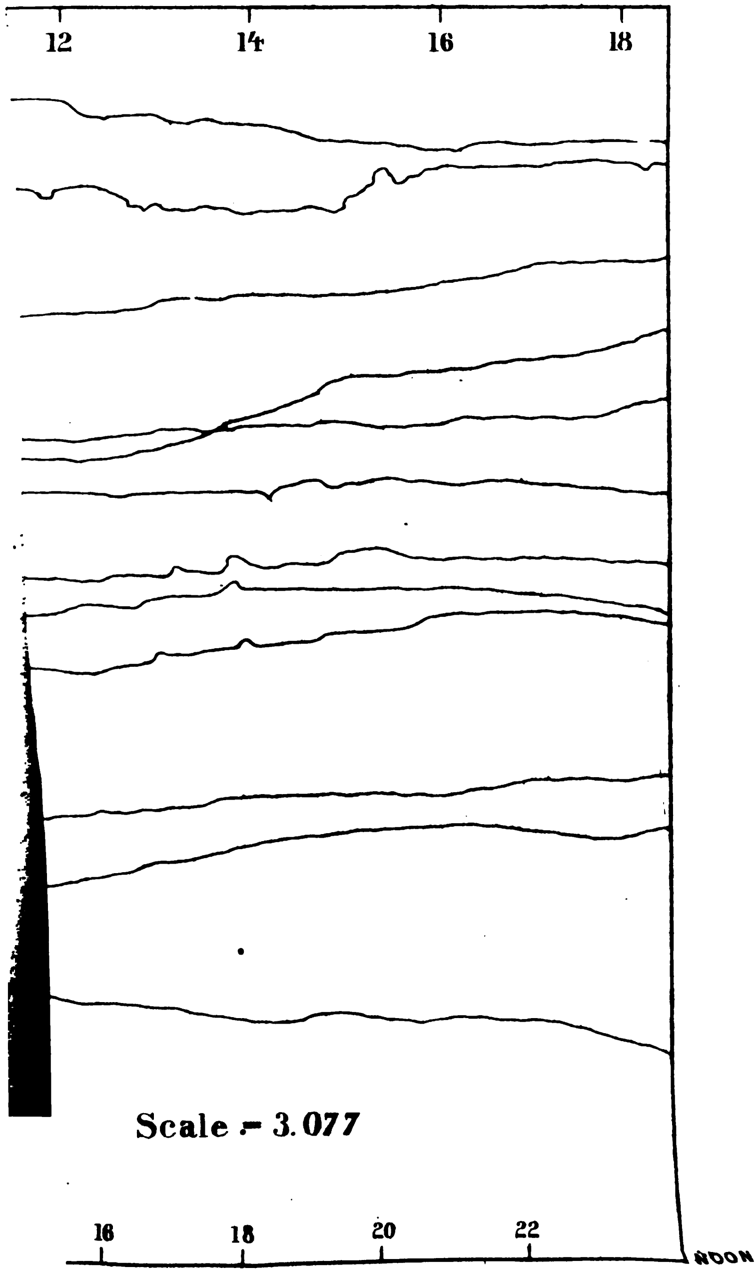
DUDLEY OBSERVATORY.

MAY 11TH, 1865.

TIME.	BAROMETER.		
	29 *in.*		
HOURS.			
0	7	0	4
1	6	9	6
2	7	0	9
3	6	8	8
4	6	9	2
5	6	8	1
6	6	9	0
7	6	8	9
8	6	8	0
9	6	6	2
10	6	5	8
11	6	7	0
12	7	3	6
13	7	0	0
14	7	0	1
15	7	1	8
16	7	7	6
17	7	8	3
18	7	8	4
19	7	8	9
20	7	9	0
21	7	8	3
22	7	8	5
23	8	0	1
0	8	0	4

Automatic registering

rvatory, Albany, N.Y.



The accompanying lithographic sheet exhibits a few of the more remarkable diurnal barometric curves, as recorded by our apparatus. The first three curves belong to the scale as given at the top of the sheet; the remaining ones to that given at the bottom. The height of the barometer is given for noon of each day. The scale of the curve is 3.077 times the barometric pressure.

The following remarks will show the apparent atmospheric condition at the time:

May 10th. Bar. 29.91 in. Cloudy, a light breeze from the south. The violent agitation of the barometrical column clearly indicates an approaching storm. The small amount of depression, however, shows that this storm will not be very violent at the place of observation.

We may here remark, that a few months of observation by this method has led us to surmise that the barometer, as a weather indicator, does not depend so much upon the amount of the variation as upon its quality. If the barometer is depressed 0.2 or 0.3 of an inch, and the curve is smooth and regular, it does not indicate a sudden change. But, if the curve exhibits a violent tremor, it may be taken as a good indication of an approaching storm. In how far these views are correct can only be determined by a long series of careful observations.

May 11th. Bar. 29.70 in. The curve is rather a remarkable one, from the fact that apparently there was but little atmospheric disturbance at this place. It shows, however, that the atmosphere was in a violent state of agitation from 3 P. M., of the 11th, to 4 A. M., of the 12th. During the afternoon of the 11th, the weather was very changeable; clouds were continually passing over the heavens. At 6 P. M. it began to rain, and continued, with intervals of intermission, until some time after midnight. During the afternoon and evening, the wind blew rather strongly from the

southwest, but was at no time very violent here. But at other points 200 miles to the east and south of this city, the wind blew a tornado, doing considerable damage to property. At New York, it was most violent between 6 and 7 P. M.

June 26th. Bar. 29.68 in. Cloudy: a heavy shower of rain followed immediately after the depression at 4 P. M. A violent gale of wind 150 miles to the east, about midnight.

July 16th. Bar. 29.81 in. Rain after 8 P. M.

July 19th. Bar. 29.69 in. Rain.

July 26th. Bar. 29.60 in. Cloudy; light breeze from south.

Aug. 4th. Bar. 29.94 in. Heavy showers from 6 to 10 P. M.

Aug. 12th. Bar. 29.72 in. Clear and pleasant.

Aug. 16th. Bar. 29.73 in. Rain storm between 6 and 8 P. M.

Aug. 22d. Bar. 29.65 in. Rain.

Aug. 29th. Bar. 29.94 in. Clear.

Oct. 17th. Bar. 30.20 in. Clear.

Oct. 18th. Bar. 30.04 in Cloudy, with some rain. A violent gale of wind on the night of the 19th; most severely felt along the eastern coast. The observations of the 17th and 18th of October were made at New York city. At 14 h. the weight for driving the mechanism rested on the floor. The barometer, at 9 A. M. of the 19th, stood at 29.40 in.

The chief sources of error in barometrical results are two-fold.

1st. That due to uncertainty in the value of the coefficient of expansion, for the material used.

2d. That due to the uncertainty in the determination of the temperature of the mercurial column.

The first will have nearly a constant effect, and for purposes of intercomparison of results, made with the same instrument, may be neglected. But the second has a very important bearing on the accuracy of the results.

The methods most commonly employed for attaching the uermometer, are either to immerse the bulb in the cistern or ix it against the side of the column. In neither case do we et the temperature of the column itself, especially if the uanges are rapid. Perhaps the best method now in use, is o make the thermometer bulb of the same size as the barometrical column.

From many experiments made during the past year, to etermine the effect of temperature, and a full discussion of ne results, we decided to employ a siphon proper, which hould have the elements of compensation within itself, iereby avoiding the uncertain temperature corrections. ut we are not limited exclusively to this form, since an rdinary cistern barometer could have been used with equal icility, by simply inverting it and bending the lower end in siphon form. With this we would get nearly double the notion which we now obtain, for the same amount of ressure; but there would be a variable correction which it vould be necessary to apply to every record, for eliminating he error due to capacity of cistern. By making the cistern arge in diameter and the siphon small, this correction might e reduced to a small quantity; yet where we desire accurate esults, it would nevertheless be necessary to apply it.

Aside from this objection there is another of still greater veight, viz.: the error due to the temperature. A barometer tube in this form might be compensated by suspending it on a combination of metallic rods, but from many experiments which we have lately made, we do not consider this mode of compensation reliable, since during sudden changes of temperature the rods will be affected long before the mercury in he barometer tube, especially if it be of large dimensions. And we are fully persuaded that the errors of temperature vould more than counterbalance the benefit arising from a reater extent of scale. It has been suggested to me to use

a steel siphon with the upper leg one hundred times the area of the lower one. This would give us the advantage of nearly double the scale now obtained, but the uncertain temperature error has led me to reject this form entirely.

The idea of a compensating siphon, was first suggested to me by Dr. JAMES LEWIS, who proposed to secure the necessary conditions by making the upper and lower legs in the form of a conical frustrum. We propose to accomplish the same thing, by employing a certain volume of mercury.

The whole theory of a siphon compensation depends on this fundamental proposition, viz.: If the atmosphere will support 30 inches of mercury at 0° Centigrade, at 100° C. it will support $30+30e=30.540$ inches; e being equal to 0.018, the expansion in volume of mercury for 100° C. If now in a siphon barometer, the increased length of the *whole column*, when the temperature is raised from 0° to 100° C., is equal to $30e=0.540$ inches; the surface of the mercury in the short leg of the siphon will remain at the same zero of height for all temperatures, at 30 inches of pressure.

Put $e'=0.016$ the expansion of the mercurial column in a glass tube for 100° C.

$2m=$ length of mercury in the equal legs of the siphon, in which the diameter is unity.

$l=$ length of intermediate column.

$d=$ diameter of intermediate column.

$h=$ height for which the compensation is to be computed.

Then we have the following general formula:

$$(2m+ld^2)e'=he.$$

It is readily demonstrated that all siphons of the same diameter, in the equal legs, will require the same volume of mercury for compensation.

If the siphon be of uniform diameter throughout, it will require 33.7 inches of mercury to compensate at 30 inches of pressure.

A tube of this form will hardly give a sufficient length of mercury in the short leg. In order to attain the necessary length, we connect the two equal legs with a tube of smaller diameter.

This form is of easy construction, either for glass or steel, and it gives us a tube which can be compensated by direct experiment.

The following tables have been calculated to aid in the construction of a glass compensated siphon:

TABLE I.

d	*m*
0.70	8.5 inches.
0.75	7.2
0.80	6.0
0.85	4.6
0.90	3.1
0.95	1.5
1.00	0.0

TABLE II.

D	W
0.2 in.	0.62 lbs. Troy.
0.3	1.41
0.4	2.50
0.5	3.91
0.6	5.61
0.7	7.66
0.8	10.00
0.9	12.67
1.0	15.64

In computing these tables $h = 30$ inches, $l = 34$ inches.

D = diameter of the equal legs. W = weight of mercury necessary to compensate.

Table I, shows the length of the column of mercury in the equal legs, for different values of *d;* the diameter of the equal legs of the siphon being regarded as unity.

Table II, shows the volume or weight of mercury necessary to compensate a siphon, without regard to its shape, provided the upper and lower surfaces are equal.

If we employ a steel siphon, it will be as well to use a tube of equal diameter throughout, connecting the two legs by means of a short tube of smaller diameter. At 30 inches

of pressure a steel tube will require about 36 inches of mercury.

In the construction of a glass siphon, it will be best to adopt $d = 0.80$. After the tube is filled to the theoretical height, the whole apparatus can be subjected to different degrees of temperature, in the same manner as the compensation of a pendulum. By reading the standard barometer every quarter hour, during the progress of the experiment, the exact error of compensation can be determined; and by adding or subtracting mercury, the compensation can be perfected. In a siphon that is compensated for 30 inches of pressure, the correction for different degrees of pressure and temperature will be very small; since for 1 inch and 100° C., the correction will only amount to 0.018 inches. The largest correction required will rarely amount to 0.004 inches.

One of the peculiarities of this method is, that we can print our results at any number of places, provided we have telegraphic communication. One standard barometer may be made to record its indications at fifty different points at the same instant.

This method may be employed for measuring the fall of rain, and the results can be printed to thousandths of inches every hour, or as often as it is desirable. The general plan will be to receive the rain in a glass siphon containing mercury. One leg of the siphon may be inserted in a brass tube of uniform diameter, of 3 feet in height. Let us suppose that the mercury stands three inches high in each leg of the siphon. If water be poured in the brass tube, the mercury will of course rise in the short leg, and may be made to support a float with machinery precisely similar to that used for the barometer. The area of the vessel receiving the rain can be such that the mercury in rising will measure the amount

of rain fallen in decimal parts of an inch. When the water is drawn off, the machine will of itself come back to zero. If desirable, the apparatus for carrying ten can be so modified that it shall only act in one direction, viz.: when the mercury is rising in the short leg; in this case, we would, at the end of every month, have the total amount of rain fallen, and the same for the year. This form would probably be preferable, because when the water is drawn off, if any quantity should remain in the tube, it would have no effect on the accuracy of the results.

In applying this principle to the registration of the temperature we would use a simple metallic thermometer. A motion of two or three inches for 100 degrees Centigrade is amply sufficient to measure with certainty tenths of a degree. After having determined the scale of the instrument, it becomes an easy matter to adapt mechanism which shall print the results in degrees and decimals, without the necessity of any subsequent reductions. The curve for temperature and rain can be recorded on the same cylinder. One battery will be sufficient for all the instruments.

For the registration of the force and direction of the wind, the printing portion of the mechanism will be of great value; since it will be an easy matter to connect it with an Anemometer, so as to print the direction in degrees of the circumference, and the force or velocity in pounds or miles. Whether this method can be applied successfully to magnetical instruments, remains to be determined; but without having made any experiments in this direction, we see no serious obstacle in the way of its application.

The error of reading a first class standard barometer is considerable; chiefly owing to the difficulty in bringing the surface of the mercury in the cistern to the zero of height. We speak now of that class of barometers where the surface

of the mercury in the cistern is brought in contact with the point of an ivory pin. The uncertainty of making an exact contact may affect the readings to the extent of 0.008 of an inch. The mean error for reading our standard barometer (Fastré), tube of one-half inch diameter, and cistern of two inches diameter, is nearly 0.004 of an inch. We also find that there is a personal equation existing between the readings of two observers, mostly due to this cause. This personality, between my assistant, Mr. McClure, and myself, amounts in the maximum to 0.005 of an inch. It is also found that readings made by the light of a lamp are not the same as the daylight readings; the difference in some cases amounting to 0.010 of an inch.

It is proposed to obviate a large source of these difficulties by using electrical contact to bring the surface of the mercury in the cistern to the zero. This can readily be done at fixed stations, where meteorological observations are carried on, with but little trouble. In place of the ivory pin usually employed, we would substitute a double platinum pin, one point of which should pass through a small metal disk resting on the surface of the mercury in the cistern, and the other, placed above the surface of the disk. If these two pins are insulated, and connected with the poles of a galvanic battery, when the mercury in the cistern is raised, bringing the metal disk in contact with the platinum point, the current will be established, and an audible signal can be given by means of an electro-magnet. By this means we eliminate all errors and personal equation, in determining the zero of the cistern; and consequently the remaining error of reading will be confined to the bisection of the upper surface. The actual test of the magnetic connection as applied to our barometer gave the following results. We would remark, however, that no metal disk was employed, but one platinum wire was

plunged directly into the mercury, and the other was made of the same length as the ivory pin, and only touched the surface when the contact was made for bringing the mercury in the cistern to zero.

A large number of readings made by Mr. McClure and myself, showed that by this method the personal equation was entirely eliminated; the mean of five or ten consecutive readings not differing by an appreciable quantity. The mean error for a single reading amounted to 0.001 of an inch, and the maximum error to 0.002 of an inch; showing conclusively that the chief source of error in reading a barometer lies in the adjustment of the surface of the mercury in the cistern to the zero.

As this method of recording meteorological phenomena is new and totally different from any now in use, we have thought proper to append the hourly results, as printed by the machine. During a portion of the months of September and October, the machine was set up in New York city; we have, accordingly, omitted the observations in those months.

The first column is the day of the month. The second is the hight of the barometer in inches and decimals. The remaining columns give only the thousandths of inches; the integer inches being inferred from the numbers in the second column.

The last two columns give the sum and mean for each day. The two horizontal columns at the bottom of each table, give the sum and mean for each hour, for the whole month.

The day is in astronomical time; 0h being noon.

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METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

JUNE, 1865.

DAY.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.
1.....	29.806	807	815	822	821	821	815	825	842
2.....	29.848	854	874	880	888	....	....	....	....
3.....	29.821	821	834	836	833	829	821	814	....
4.....	29.778	789	790	794	799	800	803	817	857
5.....	30.071	090	111	103	104	111	110	135	150
6.....	30.104	107	105	098	074	063	032	023	022
7.....	29.829	823	820	813	813	814	812	810	827
8.....	29.910	921	917	918	....	....	....	....	....
9.....	29.786	778	771	752	739	710	700	699	693
10.....	29.780	805	814	826	830	835	848	855	876
11.....	29.842	845	840	839	826	823	824	820	817
12.....	29.667	678	688	694	691	689	697	704	729
13.....	29.902	910	917	927	939	948	955	965	985
14.....	30.028	048	063	072	077	087	100	110	125
15.....	30.129	127	123	108	093	094	101	092	093
16.....	29.994	995	000	001	998	998	990	989	010
17.....	29.908	917	915	915	913	908	907	908	915
18.....	29.898	897	903	909	910	910	902	903	904
19.....	29.883	880	883	875	872	867	861	862	868
20.....	29.860	870	872	863	857	857	855	852	856
21.....	29.828	828	833	842	848	848	848	853	866
22.....	29.889	899	895	894	906	920	930	952	978
23.....	30.021	027	046	050	052	048	045	048	057
24.....	29.892	892	888	889	883	879	871	863	853
25.....	29.734	746	751	742	737	731	721	720	721
26.....	29.560	509	500	507	527	545	546	563	593
27.....	29.764	774	775	776	771	....	....	....	....
28.....	29.880	887	882	881	878	879	876	872	869
29.....	29.684	687	687	686	663	662	659	659	673
30.....	29.751	762	766	777	763	748	753	774	787
Sum,..	22.504	22.603	22.678	22.679	22.613	22.595	22.561	22.673	22.966
Mean,.	29.865	29.869	29.872	29.872	29.870	29.869	29.868	29.872	29.883

REMARKS.

June 1st, clear; smoky; wind W.
" 2d, cloudy.
" 3d, fair.
" 4th, hazy.
" 5th, sprinkle of rain.
" 6th, and 7th, changeable.
" 8th, clear.
" 9th, rain at 6 P. M., with thunder and lightning; rain fall $0^{in}.41$.
" 10th, rain fall $0^{in}.97$.
" 11th, cloudy.
" 12th, 13th, 14th, clear and pleasant.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	29.875
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	29.857
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	29.849
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	29.908
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	30.022
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29.895
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29.730
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.099	29.587
[illegible]	29	—	—	—	[illegible]	[illegible]	11.392	29.724
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20.662	29.861
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.425	29.684
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18.121	29.755
Sum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	......
Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	......

REMARKS.

June 15th, cloudy.
" 16th, sprinkle of rain; wind S.
" 17th, clear.
" 18th, 19th, 20th, 21st, 22d, changeable.
" 23d, 24th, clear.
" 25th, cloudy; thunder.
" 26th, rain fall 0^{in}.68.
" 27th, rain fall 1^{in}.00.
" 28th, 29th, clear.
" 30th, changeable.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

JULY, 1865.

DAY.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.
1.	29.845	838	829	820	811	802	793	784	775
2.	29.643	634	632	624	619	638	657	676	695
3.	29.803	792	792	792	793	794	795	790	795
4.	29.779	766	751	745	739	733	733	729	742
5.	29.804	803	805	805	814	827	845	859	888
6.	29.993	972	943	909	902	887	861	855	841
7.	29.609	611	606	612	615	626	651	653	666
8.	29.764	742	733	711	699	690	684	689	692
9.	29.771	771	772	773	771	770	773	793	832
10.	29.937	919	909	888	875	858	853	844	815
11.	29.712	710	692	687	671	665	653	652	653
12.	29.732	723	708	696	688	679	669	670	672
13.	29.755	755	765	772	778	783	793	812	808
14.	29.883	870	860	854	851	852	856	862	868
15.	29.873	862	850	841	831	825	823	826	835
16.	29.810	777	788	771	737	709	700	688	646
17.	29.536	544	553	556	552	546	558	585	607
18.	29.663	657	648	642	635	630	627	640	649
19.	29.686	671	649	626	610	578	557	537	525
20.	29.660	683	692	690	707	708	730	745	760
21.	29.822	819	825	828	822	820	829	851	862
22.	29.925	912	900	888	875	861	848	845	854
23.	29.865	848	833	826	819	817	811	813	816
24.	29.857	851	839	831	826	828	823	822	846
25.	29.788	772	756	714	688	666	638	622	607
26.	29.597	588	585	590	595	607	606	606	617
27.	29.665	659	647	646	652	642	654	669	690
28.	29.720	704	707	684	672	665	649	660	668
29.	29.724	736	748	752	755	755	780	797	803
30.	29.979	969	967	968	975	975	975	994	008
31.	30.180	165	162	145	143	140	137	130	139
Sum, ..	24.380	24.123	23.946	23.686	23.520	23.376	23.361	23.498	23.674
Mean, .	29.786	29.778	29.772	29.764	29.759	29.754	29.754	29.758	29.764

REMARKS.

July 1st, cloudy; rain fall $0^{in}.18$.
" 2d, cloudy; rain fall $0^{in}.66$; wind S. W.
" 3d, clear.
" 4th, changeable.
" 5th, clear.
" 6th, cloudy.
" 7th, shower of rain, with thunder; rain fall $0^{in}.24$.
" 8th, cloudy.
" 9th, clear.
" 10th, clear.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

July, 1865.

DAY.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.
1.....	29.772	758	732	698	693	683	644	632	631
2.....	29.714	734	745	740	744	744	737	750	767
3.....	29.811	809	809	805	804	796	792	792	792
4.....	29.757	764	765	763	751	744	756	767	779
5.....	29.920	945	965	953	958	944	948	969	987
6.....	29.829	813	779	751	698	664	658	643	608
7.....	29.686	700	722	722	713	705	710	722	737
8.....	29.708	706	706	707	708	708	709	710	711
9.....	29.873	891	919	942	945	949	957	965	967
10.....	29.820	816	817	818	812	808	796	772	768
11.....	29.681	692	702	700	704	710	711	712	735
12.....	29.682	678	669	662	646	631	607	605	622
13.....	29.818	825	821	816	812	812	812	819	836
14.....	29.884	888	894	892	893	891	892	894	907
15.....	29.854	854	854	854	850	840	830	828	827
16.....	29.634	607	568	533	479	457	467	480	495
17.....	29.625	643	648	648	645	641	640	655	668
18.....	29.658	677	683	694	694	692	692	697	711
19.....	29.525	516	497	497	473	465	464	477	498
20.....	29.775	790	799	801	800	798	799	804	805
21.....	29.871	878	890	903	908	906	904	906	914
22.....	29.864	867	864	871	873	877	881	900	897
23.....	29.827	838	831	823	827	832	832	835	846
24.....	29.866	871	874	872	869	865	857	864	860
25.....	29.615	615	624	610	595	587	571	573	581
26.....	29.637	634	625	620	622	627	631	649	668
27.....	29.703	713	717	712	720	718	719	726	747
28.....	29.669	660	669	662	655	628	607	590	601
29.....	29.820	854	879	866	867	869	869	914	942
30.....	30.042	062	074	084	092	101	108	120	137
31.....	30.153	173	169	177	178	183	192	209	223
Sum,..	24.093	24.271	24.310	24.196	24.028	23.875	23.792	23.979	24.267
Mean,.	29.777	29.783	29.784	29.780	29.775	29.770	29.767	29.773	29.783

REMARKS.

July 11th, changeable.
" 12th, cloudy.
" 13th, cloudy.
" 14th, clear.
" 15th, cloudy.
" 16th, shower of rain; rain fall $0^{in}.46$.
" 17th, rain fall $1^{in}.30$; wind W.
" 18th, clear.
" 19th, changeable; rain fall $0^{in}.64$.
" 20th, clear.
" 21st, clear.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

JULY, 1865.

DAY.	18h.	19h.	20h.	21h.	22h.	23h.	Sum.	Mean.
1.......	29.631	627	620	628	629	643	17.318	29.722
2.......	29.773	776	800	816	817	813	17.288	29.720
3.......	29.790	786	807	785	787	783	19.094	29.796
4.......	29.790	802	814	809	807	800	18.385	29.766
5.......	30.000	012	023	019	012	007	22.112	29.921
6.......	29.605	592	590	601	596	593	18 183	29.758
7.......	29.761	773	781	775	778	769	16.703	29.696
8.......	29.720	731	739	751	764	767	17.249	29.719
9.......	29.971	983	981	973	966	951	21.259	29.886
10.......	29.766	764	756	745	733	714	19.603	29.817
11.......	29.743	750	753	748	744	735	16.915	29.705
12.......	29.643	675	706	729	728	743	16.263	29.678
13.......	29.850	871	887	886	890	884	19.660	29.819
14.......	29.921	928	923	908	901	889	21.261	29.886
15.......	29.827	827	827	818	800	805	20.061	29.836
16.......	29.496	502	501	503	520	530	14.398	29.600
17.......	29.680	693	703	698	690	680	14.994	29.625
18.......	29.726	727	736	731	723	705	16.340	29 681
19.......	29.537	582	611	616	636	652	13.485	29.562
20.......	29 805	822	833	830	823	823	18.482	29.770
21.......	29.923	932	941	934	931	937	21.156	29.881
22.......	29.905	911	906	904	892	886	21.206	29.884
23.......	29 860	866	872	875	868	870	20.150	29.840
24.......	29.867	858	854	840	826	801	20.367	29.849
25.......	29.579	583	593	586	595	606	15.164	29.632
26.......	29.668	680	679	681	679	667	15.158	29.632
27.......	29.749	749	745	744	745	727	16.859	29.702
28.......	29.610	610	699	724	715	713	15.941	29.664
29.......	29.940	979	978	994	986	986	20.593	29.858
30.......	30.158	183	212	219	215	194	9.811	30 076
31.......	30 232	256	249	252	251	243	4.481	30.187
Sum,...	24.526	24.830	25.119	25.125	25.047	24.916	......	......
Mean,..	29.791	29.801	29.810	29.810	29.808	29.804	......	......

REMARKS.

July 22d, clear.
" 23d, clear.
" 24th, clear.
" 25th, cloudy; rain fall $0^{in}.12$.
" 26th, rain fall $0^{in}.16$.
" 27th, changeable.
" 28th, cloudy.
" 29th, cloudy.
" 30th, clear.
" 31st, clear.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

AUGUST, 1865.

DAY.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.
1.....	30.225	212	98	180	165	157	148	150	176
2.....	30.162	142	116	098	076	071	056	051	052
3.....	30.011	991	979	971	968	964	961	956	972
4.....	29.941	916	894	872	864	861	874	911	890
5.....	29.917	912	898	878	875	869	870	890	891
6.....	29.753	720	702	666	644	621	612	615	594
7.....	29.532	537	547	543	562	579	600	624	637
8.....	29.811	806	801	796	791	786	788	793	821
9.....	29.866	847	828	821	803	798	792	790	806
10.....	29.661	632	611	606	585	580	563	561	564
11.....	29.554	554	555	563	551	569	587	607	639
12.....	29.717	718	712	704	704	714	720	729	751
13.....	29.883	873	864	851	844	839	831	841	856
14.....	29.865	852	831	824	818	813	803	804	806
15.....	29.787	769	758	736	713	713	713	732	741
16.....	29.735	728	717	708	716	731	741	780	778
17.....	29.943	931	915	904	901	903	907	907	926
18.....	29.946	933	918	906	903	890	885	889	904
19.....	29.859	830	812	797	791	802	806	810	814
20.....	29.794	776	751	726	710	706	703	713	723
21.....	29.586	565	553	530	513	512	523	542	572
22.....	29.650	637	621	636	629	609	603	601	611
23.....	29.662	664	669	675	682	701	717	751	757
24.....	29.888	881	874	867	860	853	867	885	909
25.....	29.994	983	970	959	964	967	978	984	989
26.....	29.909	895	861	831	820	814	819	817	826
27.....	29.752	755	751	753	752	765	777	797	822
28.....	29.901	888	867	850	842	839	847	862	870
29.....	29.944	935	918	903	898	902	911	924	940
30.....	30.094	083	070	062	057	043	051	054	067
31.....	30.029	008	979	957	941	935	927	929	943
Sum,..	26.371	25.973	25.540	25.173	24.942	24.906	24.980	25.299	25.647
Mean,.	29.851	29.838	29.824	29.812	29.805	29.803	29.806	29.816	29.827

REMARKS.

August 1st, clear.
" 2d, clear.
" 3d, cloudy.
" 4th, clear; rain from 6h. to 10h.; rain fall $0^{in}.22$.
" 5th, changeable.
" 6th, cloudy; wind S.
" 7th, clear.
" 8th, clear.
" 9th, clear.
" 10th, cloudy.
" 11th, cloudy.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

AUGUST, 1865.

DAY.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.
1.	30.176	204	189	195	196	188	184	183	179
2.	30.064	063	067	063	069	065	060	060	062
3.	29.974	974	974	974	957	950	953	952	962
4.	29.903	911	901	891	900	886	898	894	917
5.	29.908	914	903	903	901	891	877	877	873
6.	29.589	581	558	547	530	516	505	502	511
7.	29.669	669	663	668	669	692	701	721	748
8.	29.847	844	861	866	867	864	866	869	880
9.	29.798	796	795	790	776	776	771	768	769
10.	29.565	559	550	546	544	544	548	555	557
11.	29.635	637	638	650	660	658	671	671	691
12.	29.791	804	817	858	837	848	862	882	895
13.	29.859	860	868	869	874	875	876	878	902
14.	29.818	815	815	823	816	809	809	809	819
15.	29.763	742	737	736	737	737	728	715	732
16.	29.817	824	835	856	852	860	860	869	884
17.	29.932	941	941	942	948	956	956	951	958
18.	29.907	908	908	906	901	893	884	891	884
19.	29.817	821	827	828	825	827	831	836	841
20.	29.728	723	720	709	695	680	664	662	666
21.	29.583	585	585	574	549	557	568	569	569
22.	29.629	616	596	590	581	592	596	602	608
23.	29.769	776	783	791	803	800	808	823	839
24.	29.926	945	959	963	977	975	975	990	005
25.	30.004	001	999	993	006	010	009	019	015
26.	29.819	819	812	785	777	767	754	755	756
27.	29.833	848	855	855	857	859	864	866	883
28.	29.873	882	887	903	900	901	917	917	932
29.	29.958	974	989	008	016	019	022	032	064
30.	30.069	080	070	065	065	061	055	056	059
31.	29.950	951	949	949	945	938	921	921	921
Sum, ..	25.973	26.067	26.051	26.096	26.030	25.994	25.993	26.095	26.381
Mean, .	29.838	29.841	29.840	29.842	29.840	29.838	29.838	29.842	29.851

REMARKS.

August 12th, clear.
" 13th, clear.
" 14th, clear.
" 15th, clear.
" 16th, clear; smoky; shower of rain at night; rain fall $0^{in}.32$.
" 17th, clear.
" 18th, clear.
" 19th, clear.
" 20th, clear.
" 21st, cloudy.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

AUGUST, 1865.

DAY.	18h.	19h.	20h.	21h.	22h.	23h.	Sum.	Mean.
1.......	30.182	218	215	206	198	184	4 508	30.188
2.......	30.063	059	057	040	039	027	1.682	30.070
3.......	29 975	976	976	978	968	954	22.270	29.970
4.......	29 940	924	941	932	932	932	21.725	29.905
5.......	29.866	859	858	842	819	791	21.082	29.878
6.......	29.509	511	513	513	537	531	13.880	29.578
7.......	29.787	797	798	818	803	816	16.180	29.674
8.......	29.893	893	889	888	885	878	20.283	29.845
9.......	29.769	753	744	735	710	686	18.787	29.783
10.......	29.559	555	554	555	557	557	13.668	29.569
11.......	29.690	716	733	731	729	722	15.411	29.642
12.......	29.929	911	912	910	905	888	19.518	29.813
13.......	29.927	917	918	912	902	887	21.006	29.875
14.......	29.836	834	828	824	822	807	19.700	29.821
15.......	29.755	752	754	765	755	752	17.822	29.743
16.......	29.924	930	936	969	960	951	19.961	29.832
17.......	29.992	004	999	992	983	956	21.688	29.945
18.......	29.903	895	897	887	884	873	21.595	29.900
19.......	29.848	853	842	836	832	823	19.808	29.825
20.......	29.672	669	662	658	636	605	16.751	29.698
21.......	29.614	629	640	637	656	660	13.871	29.578
22.......	29.627	631	629	644	656	660	14.854	29.619
23.......	29.855	877	872	891	905	895	18.765	29.782
24.......	30.016	030	041	034	022	014	15.756	29.948
25.......	30.016	016	008	994	974	943	13.795	29.991
26.......	29.760	776	770	762	762	760	19.226	29.801
27.......	29.905	919	929	926	935	918	20.176	29.841
28.......	29.953	961	962	962	967	959	21.642	29.902
29.......	30.084	104	113	120	116	107	12.001	30.000
30.......	30.070	077	075	077	065	054	1.579	30.066
31.......	29.921	922	911	902	882	865	20.496	29.937
Sum,...	26.840	26.968	26.976	26.940	26.796	26.455	......	......
Mean,..	29.866	29.870	28.870	29.869	29.864	29.853	......	......

REMARKS.

August 22d, cloudy; sprinkle of rain.
" 23d, changeable.
" 24th, clear.
" 25th, clear; shower at night; rain fall $0^{in}.43$.
" 26th, changeable.
" 27th, cloudy.
" 28th, changeable.
" 29th, clear; smoky.
" 30th, clear; smoky.
" 31st, changeable.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

NOVEMBER, 1865.

DAY.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.
1.....	30.183	173	162	155	148	116	136	135	116
2.....	29.836	825	817	811	809	822	820	834	822
3.....	29.949	924	916	919	921	917	923	932	924
4.....	29.713	657	638	584	551	495	461	409	395
5.....	29.324	343	364	400	435	466	504	546	576
6.....	29.724	675	630	604	604	612	609	617	600
7.....	30.040	066	097	124	163	192	217	245	267
8.....	30.318	291	260	240	209	190	168	149	127
9.....	29.963	972	984	004	024	048	069	083	098
10.....	30.326	326	327	341	352	372	401	418	441
11.....	30.493	465	448	439	434	423	421	421	419
12.....	30.241	197	160	133	105	082	068	044	021
13.....	29.769	748	744	731	722	724	731	734	735
14.....	29 697	690	685	687	698	703	717	724	729
15.....	29.771	752	749	738	735	738	743	754	764
16.....	29.880	865	855	852	852	850	850	841	831
17.....	29.636	593	584	584	584	602	615	677	725
18.....	29.930	918	913	925	918	922	932	937	956
19.....	30.018	020	001	005	031	029	046	050	069
20.....	30.148	130	117	104	099	094	091	076	065
21.....	29.655	604	562	527	484	468	448	405	368
22.....	29.253	257	261	272	292	312	337	339	341
23.....	29.500	505	511	529	553	576	608	637	650
24.....	29.804	800	803	804	813	819	843	846	843
25.....	29.814	802	799	797	804	804	807	813	813
26.....	29.821	808	793	793	795	802	805	810	811
27.....	29.683	660	642	635	625	622	625	636	628
28.....	......	....	....	....	....	....	....	....	....
29.....	30.008	997	972	967	959	955	958	946	933
30.....	29.672	632	604	570	538	515	512	477	440
Sum,..	25.169	24.695	24.398	24.274	24.257	24.270	24.465	24.535	24.507
Mean,.	29.868	29.851	29.841	29.837	29.836	29.837	29.844	29.846	29.845

REMARKS.

Nov. 1st, rain and high S. wind, from 16th h. to noon of the 2d.
" 2d, cloudy.
" 3d, rain after midnight, continued without intermission until after midnight of the 4th.
" 4th, high wind from the N. W. began to blow at 11h. 30m. A. M.
" 5th, wind continued violent until 8 P. M.
" 6th, high wind from S. W.
" 7th, clear.
" 8th, clear and pleasant.
" 9th, cloudy.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

November, 1865.

DAY.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.
1.....	30.110	112	106	095	081	043	024	003	994
2.....	29.859	857	857	861	865	876	876	881	886
3.....	29.911	924	905	902	902	895	880	856	843
4.....	29.377	353	334	325	330	321	316	316	323
5.....	29.613	638	667	701	727	755	767	798	806
6.....	29.605	613	621	636	646	686	718	752	803
7.....	30.286	292	293	312	318	325	336	337	346
8.....	30.115	084	060	064	029	003	972	959	941
9.....	30.120	135	152	175	185	202	208	220	239
10.....	30.457	467	469	473	471	464	472	479	478
11.....	30.413	406	398	394	374	372	353	342	337
12.....	29.996	971	959	945	928	918	906	893	884
13.....	29.730	728	725	728	735	733	737	737	739
14.....	29.733	741	741	727	727	743	737	761	768
15.....	29.771	782	795	805	812	816	815	826	841
16.....	29.827	825	816	815	800	788	775	761	745
17.....	29.764	803	824	840	827	878	867	869	866
18.....	29.953	957	959	963	947	941	949	965	941
19.....	30.078	088	084	077	083	106	120	123	124
20.....	30.052	062	014	009	978	928	894	900	876
21.....	29.340	304	278	275	252	255	257	245	236
22.....	29.341	345	353	357	365	369	374	382	397
23.....	29.664	675	685	695	706	719	724	736	747
24.....	29.846	847	847	839	835	834	828	823	824
25.....	29.813	807	805	793	784	777	780	792	794
26.....	29.814	816	816	810	804	798	774	766	757
27.....	29.644	649	720	749	775	816	822	838	852
28.....	......	....	....	....	....	....	....	....	....
29.....	29.920	906	876	858	848	840	822	795	796
30.....	29.394	402	361	317	299	292	279	266	252
Sum,..	24.546	24.589	24.520	24.540	24.433	24.493	24.382	24.421	24.435
Mean,.	29.846	29.848	29.846	29.846	29.842	29.845	29.841	29.842	29.843

REMARKS.

Nov. 10th, cloudy.
" 11th, changeable.
" 12th, changeable.
" 13th, cloudy; haze.
" 14th, clear; hazy.
" 15th, clear.
" 16th, changeable.
" 17th, changeable.
" 18th, rain storm.
" 19th, rain.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

NOVEMBER, 1865.

DAY.	18h.	19h.	20h.	21h.	22h.	23h.	Sum.	Mean.
1.......	29.988	961	962	934	915	900	8.552	30.065
2.......	29.885	887	905	926	934	949	20.700	29.862
3.......	29.839	834	835	806	788	762	21.207	29.884
4.......	29.320	316	318	308	312	330	9.802	29.408
5.......	29.810	826	829	822	804	783	15.304	29.638
6.......	29.847	898	940	975	003	026	15.444	29.727
7.......	30.341	342	356	357	353	342	6.347	30.264
8.......	29.930	931	940	945	958	958	10.841	30.077
9.......	30.248	285	302	331	336	342	6.725	30.155
10.......	30.492	503	510	511	514	514	10.578	30.441
11.......	30.326	320	318	311	296	272	9.195	30.383
12.......	29.870	863	860	861	847	812	14.564	29.982
13.......	29.741	750	758	751	745	731	17.706	29.738
14.......	29.772	781	800	806	802	788	17.757	29.740
15.......	29.849	869	885	892	892	893	19.287	29.804
16.......	29.724	726	724	702	698	675	19.077	29.795
17.......	29.882	897	912	921	934	946	18.630	29.776
18.......	29.947	963	994	999	003	008	20.840	29.952
19.......	30.124	134	159	162	167	167	2.065	30.086
20.......	29.846	836	831	798	751	705	10.404	29.975
21.......	29.242	247	248	251	257	259	8.467	29.353
22.......	29.415	436	452	477	497	502	8.726	29.364
23.......	29.763	772	801	815	826	810	16 207	29.675
24.......	29.824	831	841	843	844	836	19.917	29.830
25.......	29.805	809	816	831	843	838	19.340	29.806
26.......	29.753	753	753	746	737	712	18.847	29.785
27.......	29.869	885	924	902	928	939	18.068	29.753
28.......	......	....	....	....	....	....	......	......
29.......	29.778	787	775	769	745	696	19.906	29.871
30.......	29.247	252	261	275	294	314	9.465	29.394
Sum,...	24.477	24.694	25.009	25.027	25.023	24.809	......	......
Mean,..	29.844	29.852	29.862	29.863	29.863	29.855	......	......

REMARKS.

Nov. 20th, rain storm.
" 21st, rain from noon of 21st to noon of 22d.
" 22d, cloudy; no wind.
" 23d, cloudy; no wind.
" 24th, cloudy.
" 25th, cloudy.
" 26th, changeable.
" 27th, one inch of snow fell after midnight,
" 28th, machine taken down to make some experiments with a new form of unlocking.
" 29th, cloudy.
" 30th, clouds moving rapidly to the S. E. at 22h., "curve indicates wind."

[illegible] OBSERVATIONS.

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]								...	...
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	509	591	486
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	695	730	740
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	781	759	778
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	862	892	922
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	790	792	800
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	243	261	291
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	113	118	121
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	154	142	133
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26.624	26.966	27.070
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29.576	29.888	29.899	29.902

REMARKS.

Dec. 1st, wind began to blow from the S. at noon.
" 2d, high S. wind continued until after midnight.
" 3d, rain during the night.
" 4th, strong breeze from N. W. began after midnight.
" 5th, wind N. W., changeable.
" 6th, began to snow at 16h.
" 7th, snow continued until 4 P. M.; fall of water, 0.2in.
" 8th, changeable.
" 9th, sprinkle of snow.
" 10th, changeable.
" 11th, clear.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

DECEMBER, 1865.

DAY.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.
1.....	29.567	610	657	652	679	717	718	727	752
2.....	29.651	650	646	660	656	685	706	717	734
3.....	30.035	036	034	027	991	968	966	952	955
4.....	29.879	907	919	910	917	931	923	928	936
5.....	30.100	081	077	059	041	036	034	027	023
6.....	29.846	832	824	783	753	706	675	637	611
7.....	29.632	687	731	759	787	826	865	901	931
8.....	30.118	119	130	132	136	152	146	159	160
9.....	29.829	779	753	715	704	690	684	680	669
10.....	29.826	819	832	835	851	886	876	870	879
11.....	30.011	013	013	008	996	986	995	985	973
12.....	29.804	823	819	802	817	815	832	867	886
13.....	30.016	011	003	999	002	006	995	991	985
14.....	30.012	017	024	997	991	993	991	984	989
15.....	30.044	049	053	051	054	061	063	069	080
16.....	.....	....	....	....	....	....	....	....	....
17.....	30.123	096	107	115	126	146	172	162	155
18.....	29.961	940	906	864	831	825	760	702	649
19.....	29.438	456	482	503	513	558	605	649	699
20.....	29.721	679	595	592	477	335	298	221	176
21.....	29.862	895	916	922	936	951	969	981	970
22.....	30.070	101	138	167	198	244	271	290	303
23.....	30.357	334	292	274	235	197	166	112	080
24.....	29.470	466	451	443	434	449	447	460	494
25.....	29.765	788	795	796	799	820	821	812	823
26.....	29.731	694	675	636	601	577	527	492	466
27.....	29.928	937	970	986	995	024	032	032	037
28.....	29.800	840	860	880	907	922	958	968	974
29.....	30.288	290	302	293	307	286	290	278	278
30.....	30 125	131	136	139	147	158	186	195	214
31.....	30.129	116	098	061	037	023	005	973	966
Sum,..	27.138	27.196	27.238	27.060	26.918	26.973	26.976	26.821	26.847
Mean,.	29.905	29.906	29.908	29.902	29.897	29.899	29.899	29.894	29.895

REMARKS.

Dec. 12th, rain from 23h. of 11th until after midnight.
" 13th, flurries of snow, wind N. W.
" 14th, high wind from N. W.
" 15th, changeable.
" 16th, machine taken down to test a new barometer tube.
" 17th, clear.
" 18th, snow at 7 P. M.; "curve indicates a gale of wind."
" 19th, no wind from 6 to 10 P. M.; violent gale of wind from the W. began at 11 P. M. Oscillation of the barometer the greatest ever before observed here.
" 20th, snow at 9 P. M.; heavy gale of wind from the W. at 20h.
" 21st, gale from W. continued until 8 P. M.
" 22d, clear.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

DECEMBER, 1865.

DAY.	18h.	19h.	20h.	21h.	22h.	23h.	Sum.	Mean.
1.......	29.757	773	797	807	830	791	14.645	29.610
2.......	29.774	823	875	905	932	932	17.536	29 731
3.......	29.934	935	921	917	901	861	15.358	29.973
4.......	29.957	974	999	015	059	056	18.519	29.897
5.......	30.017	010	002	012	010	984	2.062	30.044
6.......	29.598	559	556	525	501	427	18.121	29.755
7.......	29.957	989	011	039	051	041	13.198	29.717
8.......	30.168	181	179	194	190	164	2.897	30.121
9.......	29.678	680	694	713	721	712	15.559	29.815
10.......	29.927	914	934	955	959	960	20.167	29.840
11.......	29.981	971	970	952	957	952	17.485	29.978
12.......	29.926	976	023	071	102	083	17.409	29.892
13.......	29.995	997	000	001	008	993	7.259	30.011
14.......	30.010	027	032	038	040	011	13.682	29 987
15.......	30.086	104	119	128	135	128	4.347	30.056
16.......	....	....	....	....	....	....	......	......
17.......	30.167	170	173	175	165	162	2 843	30.118
18.......	29.617	608	586	564	551	512	12.606	29.859
19.......	29.749	831	840	898	915	900	13.740	29.572
20.......	29.179	152	132	213	302	368	13.204	29.550
21.......	29.973	954	953	968	968	928	19.628	29.818
22.......	30.334	356	382	406	404	409	11.455	30.144
23.......	30.070	020	998	919	852	775	9.080	30.212
24.......	29.500	511	555	580	603	601	12.397	29.516
25.......	29.835	849	842	865	857	846	18.143	29.756
26.......	29.482	448	420	413	438	461	15.063	29.628
27.......	30.046	039	025	026	002	951	12.394	29.891
28.......	29.999	030	054	091	126	143	16.877	29.911
29.......	30.283	291	288	282	296	239	6.121	30.255
30.......	30.237	256	275	292	300	295	4.257	30.177
31.......	29 950	942	934	938	932	916	9.720	30.072
Sum,....	27.186	27.370	27.569	27.902	28.107	27.601	......	......
Mean,...	29.906	29.912	29.919	29.931	29.937	29.920	......	......

REMARKS.

Dec. 23d, snow, wind S.
" 24th, cloudy.
" 25th, clear.
" 26th, thaw, sprinkle of rain, wind S.
" 27th, wind S.
" 28th, snow and sleet, wind N. E.; at 11 P. M. wind W.
" 29th, began to snow at 22h., wind N. W.
" 30th, snow continued to 8 P. M., fall 3 inches. This was probably an eastern storm, although the wind here was N. W. At New York and Boston, according to the reports, it began about 6 hours earlier than at this place.
" 31st, clear.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

HOURS.	MEAN FOR HOURS.					Mean of the five months.
	June.	July.	Aug.	Nov.	Dec.	
	in.	in.	in.	in.	in.	in.
0	29.887	29.786	29.851	29.868	29.879	29.854
1	.878	.778	.838	.851	.864	.842
2	.866	.772	.824	.841	m. 857	.832
3	.854	.764	.812	.837	.862	.824
4	.847	.759	.805	m. 836	.868	.823
5	m. 842	m. 754	m. 803	.837	.876	m. 822
6	.842	.754	.806	.844	.888	.827
7	.846	.758	.816	.846	.899	.833
8	.852	.764	.827	.845	.902	.838
9	.865	.777	.838	.846	.905	.846
10	.869	.783	.841	$M._o$ 848	.906	.849
11	$M._o$ 872	$M._o$ 784	.841	.846	$M._o$ 908	$M._o$ 850
12	.872	.780	$M._o$ 842	.846	.902	.848
13	.870	.775	.840	.842	.897	.845
14	.869	.770	.838	.845	.899	.844
15	$m._o$ 868	$m._o$ 767	$m._o$ 838	$m._o$ 841	.899	$m._o$ 843
16	.872	.773	.842	.842	$m._o$ 894	.845
17	.883	.783	.851	.843	.895	.851
18	.892	.791	.866	.844	.906	.860
19	.899	.801	.870	.852	.912	.867
20	M. 902	M. 810	M. 870	.862	.919	.873
21	.900	.810	.869	M. 863	.931	M. 875
22	.896	.808	.864	.863	M. 937	.874
23	.892	.804	.853	.855	.920	.865

m = the minimum of the afternoon.
M_o = the maximum of the night.
m_o = the minimum of the morning.
M = the maximum of the morning.

METEOROLOGICAL OBSERVATIONS.

TYPO-BAROGRAPH.

MEAN FOR DAYS.

DAYS.	June.	July.	August.	Nov'r.	Dec'r.
1........	29.820	29.722	30.188	30.065	29.610
2........	29.851	29.720	30.070	29.862	29.731
3........	29.844	29.796	29.970	29.884	29.973
4........	29.814	29.766	29.905	29.408	29.897
5........	30.090	29.921	29.878	29.638	30.044
6........	30.070	29.758	29.578	29.727	29.755
7........	29.840	29.696	29.674	30.264	29.717
8........	29.890	29.719	29.845	30.077	30.121
9........	29.759	29.886	29.783	30.155	29.815
10........	29.706	29.817	29.569	30.441	29.840
11........	29.835	29.705	29.642	30.383	29.978
12........	29.710	29.678	29.813	29.982	29.892
13........	29.916	29.819	29.875	29.738	30.011
14........	30.069	29.886	29.821	29.740	29.987
15........	30.118	29.836	29.743	29.804	30.056
16........	30.000	29.600	29.832	29.795	......
17........	29.921	29.625	29.945	29.776	30.118
18........	29.900	29.681	29.900	29.952	29.859
19........	29.875	29.562	29.825	30.086	29.572
20........	29.857	29.770	29.698	29.975	29.550
21........	29.849	29.881	29.578	29.353	29.818
22........	29.908	29.884	29.619	29.364	30.144
23........	30.022	29.840	29.782	29.675	30.212
24........	29.895	29.849	29.948	29.830	29.516
25........	29.730	29.632	29.991	29.806	29.756
26........	29.587	29.632	29.801	29.785	29.628
27........	29.724	29.702	29.841	29.753	29.891
28........	29.861	29.664	29.902	......	29.911
29........	29.684	29.858	30.000	29.871	30.255
30........	29.755	30.076	30.066	29.394	30.177
31........	......	30.187	29.937	......	30.072

DIURNAL MAXIMA AND MINIMA.

	Min.	Max.₀	Min.₀	Max.
June,	5 P. M.	11 P. M.	3 A. M.	8 A. M.
July,	5 "	11 "	3 "	8 "
August,	5 "	12 "	3 "	8 "
November,	4 "	10 "	3 "	9 "
December,	2 "	11 "	4 "	10 "
Mean for all,	5 "	11 "	3 "	9 "
Summer,	5 "	11 "	3 "	8 "
Autumn,	3 "	11 "	4 "	10 "

MAXIMA AND MINIMA IN EACH MONTH.

DATE.	Day.	Hour.	Max.	Day.	Hour.	Min.	Hourly Range.
			in.			*in.*	*in.*
June,	5	20	30.186	26	11	29.500	0.686
July,	31	19	30.256	16	14	29.457	0.799
August,	1	0	30.225	6	16	29.502	0.723
November,	10	22	30.514	21	17	29.236	1.278
December,	22	23	30.409	20	20	29.132	1.277

Max. Bar. recorded 30.514. Min. 29.132.

MAXIMA AND MINIMA FOR DAYS.

MONTH.	Day.	Max.	Day.	Min.	Daily Range.
		in.		*in.*	*in.*
June,	15	30.118	26	29.587	0.531
July,	31	30.187	19	29.562	0.625
August,	1	30.188	10	29.569	0.919
November,	10	30.441	21	29.353	1.091
December,	29	30.255	24	29.516	0.739

Maximum Day, Nov. 10th, $30^{in}.441$. Minimum Day, Nov. 21st, $29^{in}.353$.

[illegible] OBSERVATIONS.

[illegible]

[illegible]	[illegible]	[illegible]	August.	Mean.
[illegible]	[illegible]	[illegible]	29.840	29.829
[illegible]	[illegible]	[illegible]	839	828
[illegible]	[illegible]	[illegible]	839	828
[illegible]	[illegible]	[illegible]	838	829
[illegible]	[illegible]	[illegible]	837	829
[illegible]	[illegible]	[illegible]	837	828
[illegible]	[illegible]	[illegible]	837	828
[illegible]	[illegible]	[illegible]	837	829
[illegible]	[illegible]	[illegible]	837	828
[illegible]	[illegible]	[illegible]	836	828
[illegible]	[illegible]	[illegible]	837	829
[illegible]	[illegible]	[illegible]	838	830
[illegible]	[illegible]	[illegible]	837	831
[illegible]	[illegible]	[illegible]	838	832
[illegible]	[illegible]	[illegible]	838	832
[illegible]	[illegible]	[illegible]	837	832
[illegible]	[illegible]	[illegible]	835	831
[illegible]	[illegible]	[illegible]	835	830
[illegible]	[illegible]	[illegible]	833	828
[illegible]	[illegible]	[illegible]	831	828
[illegible]	[illegible]	[illegible]	829	827
[illegible]	[illegible]	[illegible]	831	828
[illegible]	[illegible]	788	828	828
[illegible]	[illegible]	789	831	830

[illegible] by interpolation from the hourly [illegible]. It was computed in order to determine the [illegible] in raising tides in the atmosphere.

[illegible] from one transit of the moon to the next was [illegible] lunar day, and was divided into 24 equal [illegible] representing a lunar hour; 0 hours indicating the [illegible] 12 hours the lower transit.

[illegible] results do not show any fixed maxima and minima, [illegible] indicate that the effect of the moon in raising atmospheric tides is very feeble. The subject, however, is

an interesting one, and worthy of a thorough investigation. It is our intention to attach an additional apparatus to our mechanism, so as to print the barometrical heights every lunar hour. By this plan accurate results would be attained with but a small outlay of time and labor.

We have recently attached to our instrument an additional mechanism, for counting the pulsations of the atmosphere, or the oscillations of the barometrical column. The examination of the curve will give us some idea of the amount of the oscillation, but in order to deduce the numerical results it would require a large outlay of time and labor, and the results at best would only be an approximation. As in our mechanism the wheels a, a', make a complete revolution for every change of $\frac{1}{1000}$ of an inch in the pressure, it is a simple problem to register the number of revolutions, which at once tells us how far the barometrical column has moved in a day or any other period. We have noticed that previous to, and during great storms of wind or rain, the barometrical column was in a continual state of agitation, and we were anxious to determine whether the amount of the disturbance, numerically expressed, would not afford an indication of coming weather.

This subject has not been studied for a sufficient length of time to decide positively with regard to the value of this element in indicating the weather, but we do know that the numerical record of the oscillations aid greatly in the interpretation of past phenomena.

For the thorough investigation of this subject we ought to use a barometrical column with a surface of at least one square inch. The middle of this column should support a float which would move with the least possible friction. Such a float has been devised. With such an instrument I believe the minute waves of pressure could be recorded, which cannot be observed with a column of ordinary size.

I have for some time entertained the opinion, that a delicate barometer would be affected by the small pulsations of the atmosphere, which I have imagined precede great storms, from one to three days in advance.

As the numerical record of the oscillations was not begun until about the 1st of January, 1866, but few results can be given, bearing upon this topic. We here append, however, the record for January, 1866, which if of no scientific value, may at least be of some interest, since so far as we know it is the first record of the kind which has been made.

The 1st column is the date; the 2d, h = barometrical hight at noon; 3d, m = variation of pressure in 24 hours; 4th, m' = maximum variation of pressure in 24 hours; 5th, o = number of oscillations in 24 hours, from noon of the date to the noon following; 6th, t = Fahrenheit thermometer at 8 a. m; 7th, remarks on the weather.

In the 3d column, the sign *plus*, indicates an increase and *minus*, a decrease of pressure.

From the 18th to the 22d, the assistant, during my absence, neglected to read the record of the oscillations.

It may here be remarked, that the barometer on the 8th of January, attained a higher elvation, than has probably ever before been recorded in the United States.

At 11 A. M. of the 8th, the barometrical height, reduced to 32° Fahrenheit and the level of the sea, was $31^{in}.11$, and at stations west of this place, on nearly the same parallel of latitude it stood at $31^{in}.22$. This unusual elevation of the barometer was accompanied with a corresponding depression of the thermometer. At this place the temperature was below zero for sixty consecutive hours.

METEOROLOGICAL OBSERVATIONS.

JANUARY, 1866.

DATE.	h.	m.	m′.	o.	t. 8 A. M.	REMARKS.
	in.	in.	in.	in.	°	
1	29.90	+0.23	0.30	0.672	+34	Cloudy; wind S.
2	30.13	—0.25	0.25	.424	+26	Changeable Lunar halo at 10 P. M.
3	29.88	—0.25	0.27	.330	+14	Cloudy; changeable.
4	29.63	+0.44	0.51	.760	+22	Clear; wind N W., quite brisk at 8 P. M.
5	30.07	+0.22	0.30	.690	— 6	Clear and cloudy.
6	30.29	+0.32	0.33	.522	+ 8	Cloudy; wind N. E.
7	30.61	+0.26	0.29	.354	—10	Clear; wind N. W.
8	30.87	—0.25	0.27	.317	—17	Clear; wind W.
9	30.62	—0.43	0.44	.492	— 5	Clear; wind N. W.
10	30.19	—0.35	0.37	.840	+ 7	Cloudy; wind N. W.
11	29.84	+0.03	0.07	.360	+28	Cloudy; wind S.
12	29.87	—0.43	0.43	.768	+30	Cloudy; snow at 8 P. M.
13	29.44	+0.55	0.58	.780	+35	Cloudy; high wind from N. W. after midnight.
14	29.99	+0.40	0.48	.804	+27	Strong wind from W., from noon to 10 P. M.
15	30.39	—0.82	0.82	1.200	— 5	Snow after midnight.
16	29.57	+0.25	0.33	.611	+13	Heavy gale of wind from N. W., at 10 P. M.
17	29.82	—0.11	0.22	1.032	+27	Changeable; strong wind from S. E.
18	29.71	+0.03	0.20		+29	Cloudy.
19	29.74	—0.19	0.31		+27	Cloudy.
20	29.55	+0.40	0.50		+42	Cloudy; wind S., quite brisk.
21	29.95	—0.05	0.12		+12	Clear; wind W.
22	29.90	+0.25	0.28	.360	+14	Cloudy; wind W.
23	30.15	+0.14	0.20	.288	+20	Cloudy; wind S. E.
24	30.29	—0.52	0.52	.800	+14	Began to snow at 14h; wind N. W.
25	29.77	—0.08	0.16	.612	+22	Snow; wind N. W.
26	29.69	+0.33	0.35	.792	+26	Cloudy; flurries of snow.
27	30.02	—0.01	0.03	.156	+18	Clear and cold.
28	30.01	—0.07	0.13	.192	+ 2	Changeable; sprinkle of snow.
29	29.94	—0.24	0.23	.312	+17	Cloudy; wind S.
30	29.70	—0.17	0.22	.480	+22	Wind S. W.; flurries of snow.
31	29.53	—0.24	0.25	.636	+22	Changeable; wind S. E.

The Swedish Tabulating Machine of G. & E. SCHEUTZ.

It is a well known fact that Mr. CHARLES E. BABBAGE was the first to attempt the construction of a Difference Engine; but owing to some misunderstanding between the inventor and the English government, under whose patronage the work was carried on, it was never completed.

In the Edinburgh Review for July, 1834, Dr. LARDNER gave an account of Mr. BABBAGE'S machine, which, coming under the eye of Mr. GEORGE SCHEUTZ, an eminent printer at Stockholm, he conceived the idea of building one which should do the work contemplated by Mr. BABBAGE, but on a totally different plan, as regards the details of the mechanism. After proving the practicability of his ideas in the construction of some models, it was allowed to rest for a year or two. In 1837, EDWARD, the son, took up the plan, and in conjunction with his father completed a machine of small compass in 1840. This was exhibited before the Swedish Academy of Sciences in 1843. On the certificate of that body, orders to manufacture machines were solicited in different countries, but without success. After numerous failures to secure assistance from the Swedish government, for the purpose of constructing a large and complete machine, finally in 1851, the Diet with difficulty consented to advance 5,000 rix-dollars, (about $1,500), on condition that the machine should be completed within a year, and that the inventors should give a guarantee to return that sum to the State if it did not prove successful.

Having already expended all their means in the construction of models and tools, they were unable to give the necessary guarantee, and the invention would probably have been abandoned, but for the noble liberality of fifteen members of the Swedish Academy of Sciences, who became responsible for the amount advanced.

The machine was completed in 1853, and performed its work perfectly. In consideration of the successful issue of the project, and the large sums that had been expended by the inventors, the Diet granted a reward of 5,000 rix-dollars, thus making the total grant 10,000 rix-dollars.

The machine was taken to England and exhibited before the Royal Society of London, and also placed in the great Paris Exposition, where the Gold Medal was unanimously awarded to the inventors.

It was purchased for the Dudley Observatory in 1856, at an expense of $5,000.

This machine was the only one built until 1863, when a duplicate was made for the Registrar General's Office, London, England.

This machine possesses a twofold power, with mechanism appropriate for each; not necessarily connected, though simultaneous and automatic in its entire action. These functions are, first, the production of certain numerical results; second, the conversion of those results into a permanent legible record.

The theory of the machine is based on the mathematical truth, that in any series of numbers, the *n*th order of differences may be regarded as equal to zero, where *n* may be any number whatever. To produce such a series by mechanical means, the only condition necessary is that there be as many variable wheels indicating the numbers as we have differences. If *n* was a very large number, the mechanism would become cumbersome and unwieldly. It is found in practice that for the great majority of useful computations, four orders of differences are sufficient.

This machine is constructed for four orders, and will consequently compute any series, in which the fourth (or any inferior) order of differences are equal.

This will be more easily understood by a simple illustratio Suppose it is desired to tabulate the series of square num bers beginning with unity. Let us first see how thes numbers can be produced by means of successive differences We arrange them for convenience in the following table:

Number.	Square.	1st diff.	2d diff.	3d diff.
1	1			
		3		
2	4		2	
		5		0
3	9		2	
		7		
4	16			

Having given the number (1) square of 1, and the first dif ference $3 = (2^2 - 1^2)$ and the second diff. $2 = (3^2 - 2^2) -$ $(2^2 - 1^2)$, the squares of all successive numbers may be foun by continued additions.

The difference between $(2^2 - 1^2) = 3$ is the first diff.; th second diff. (2) is constant. Then,

$(3)^2 = 9 = (2)^2 +$ 1st diff. (3) + 2d diff. (2),

or $9 = 4 + (3 + 2)$,

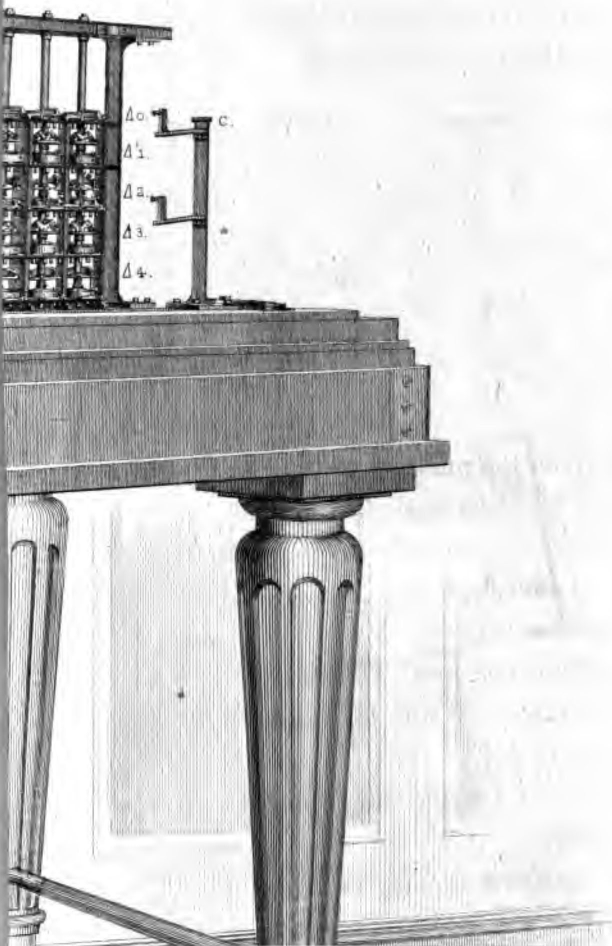
or $9 = 4 + 5$, (5) being the second number in column of first differences.

And the same process may be repeated to any extent.

What now is required in a machine, is, first to be able to produce the first order of differences, having given the firs difference 3, and the second difference (2) constant.

Suppose we have a wheel, on the circumference of which is inscribed, at equal distances apart, the numbers, 0, 1, 2, 3 4, 5, 6, 7, 8, 9. If this wheel should be set so that the figure 3 should coincide with a fixed mark, and by means of any simple mechanism, it should be made to advance two divis

PLATE IV.



ions at every motion of a lever, we should successively cause the numbers 3, 5, 7, 9, to coincide with the mark; and if when the wheel has made a complete revolution, it should cause another wheel placed by its side to advance one division, the process may be continued so as to form the series of first differences, in which every successive number would be greater by 2 than the number preceding.

This principle of successive additions is exemplified in an ordinary clock; for at every oscillation of the pendulum the second-hand advances one division, and after this has made a complete revolution, the minute-hand has also advanced one division. By a slight change in the escapement wheel, the second wheel could be made to advance 2, 3, or 4 divisions at every oscillation. Hence it will be readily understood how, by simple machinery, any *constant* quantity may be added.

Now suppose we have three wheels, placed one above the other on a vertical (shaft) axis, on each of which is inscribed zero and the nine digits, corresponding with a like number of divisions on their surfaces. If the number 1 on the upper wheel, 3 on the second wheel, and 2 on the third wheel, be brought opposite a fixed or zero point; and the nature of these wheels be such, that when set in motion by a lever from right to left, the second wheel adds its number to the upper wheel, and by a motion of the lever from left to right, the third wheel adds its number to the second (being in this case constant and always equal to 2); from this arrangement, we will be able to compute a table of square numbers.

We begin by moving the lever from right to left; when 3 (the number on the second wheel) will be added to 1 (the number on the upper wheel), making 4 the square of 2. On moving the lever back, 2 on the third wheel is added to 3 on the second wheel, making 5. Moving our lever back again from right to left, 5 is added to 4 on the upper wheel,

at zero, except the last one on the right hand, which we place at 5. Let all the rings on the second row $\triangle_1$ be set at 9. If these numbers were written down they would stand thus:

$$000\,000\,000\,000\,005 = \triangle_0.$$
$$999\,999\,999\,999\,999 = \triangle_1.$$

Now when the lever *b* is moved from right to left, every number in the row $\triangle_1$ will be added to $\triangle_0$, and the result will stand thus:

$$999\,999\,999\,999\,994 = \triangle_0.$$

It is readily perceived that the operation is not complete, since we ought to have

$$\triangle_0 = 000\,000\,000\,000\,004.$$

When the 9 is added to 5, making 14, the units ring, in passing through zero, throws out a small lever (by means of the projection between the numbers 7 and 8 shown in fig. 1). As the motion of the machine is continued, the post *c* carrying a lever arm passes in front of the rings, and by means of the lever thrown out advances the second ring a unit, making it zero, it in turn throws out the next lever to the left, when the same process is repeated, and in this example all the rings on the upper row, except the 1st, is left at zero.

In case any difference is negative, we get the same result by adding the complement, or difference between the number and 10. Suppose we wish to subtract 2 from 3, our result would be 1. If we take the complement of $2 = 8$, and add it to 3, we get $(10+1)$, or the same result on the first wheel as before. If we wish to subtract

$$000\,000\,000\,142\,346,$$

we must set on the machine the complement of this number

$$999\,999\,999\,857\,654,$$

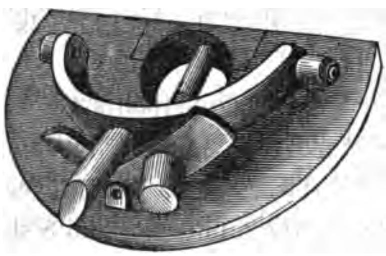
adding this complement is the same as subtracting the number itself.

By changing all the rings in the 3d and 5th vertical columns on the left, the computation can be made by the sexagesimal

free to turn about its center horizontally in either direction. A perspective view of one of these rings is shown in fig. 1.

To each of the vertical axles is attached four brass shelves, fig. 2 supporting small steel levers mounted on pivots. These levers occupy a position directly underneath the rings (fig. 1); their office being to *add* to the ring above the number coinciding with the fixed mark engraved on the ring below.

FIG. 2.



When the machine is put in operation by means of the crank *a*, the lever *b* is moved out horizontally from right to left, causing every one of the vertical axles to revolve from right to left, thereby *adding* all the numbers on the row marked $\triangle_3$ to those on $\triangle_2$, and all those on $\triangle_1$ to $\triangle_0$. By continuing to turn the crank *a*, the lever *b* is moved back again from left to right, this time adding the number on $\triangle_4$ to $\triangle_3$, and those on $\triangle_2$ to $\triangle_1$. This process is continued so long as the machine is kept in motion.

If we call the first axle to the right units, then the next one will represent tens, and the next hundreds, etc. The numbers on any row of differences is, therefore, read from left to right, as in ordinary writing.

When all the rings are set at zero, by making that division coincide with a fixed mark in front, no change will take place in their position when the machine is put in operation.

The process of carrying for 10 will best be understood by an example. Suppose all the rings in the first row $\triangle_0$ be set

During the process of making the computation, the machine also prints the result, together with the proper argument, to 8 places of figures.

A portion of the mechanism for printing, is shown at the left end of plate IV. The numbers on the upper row of rings are transferred to the printing part, by means of "the [illegible] attached to and revolving with the upper rings. This [illegible]ance shown in fig. 3, has long been used in the striking of the common eight-day clock.

The results may be stereotyped on strips of lead, or printed on ordinary paper or card-board. By changing the position of the carrying post on one of the rings, we at once obtain the nearest whole number, no matter how many decimal places are used in the computation. At the average rate of working 120 complete results are calculated and printed in one hour.

In order to compute any series of numbers, it is necessary to determine the orders of differences belonging to that series, which must be set on the proper rings.

The general formula is :

$$(n) = a + (n-1)\Delta_1 + \frac{(n-1)(n-2)}{2}\Delta_2 + \frac{(n-1)(n-2)(n-3)}{2.3}\Delta_3 + \frac{(n-1)(n-2)(n-3)(n-4)}{2.3.4}\Delta_4 + \frac{(n-1)(n-2)(n-3)(n-4)(n-5)}{2.3.4.5}\Delta_5 + \text{etc.}$$

n = the number of the term.

a = the first term.

$\Delta_1, \Delta_2, \Delta_3$, etc. = the orders of differences.

Then we have the following form of equations :

$$(1) = a$$

$$(11) = a + 10\Delta_1 + 45\Delta_2 + 120\Delta_3 + 210\Delta_4 + \text{etc.}$$

$$(21) = a + 20\Delta_1 + 190\Delta_2 + 1140\Delta_3 + 4845\Delta_4 + \text{etc.}$$

$$(31) = a + 30\Delta_1 + 435\Delta_2 + 4060\Delta_3 + 27405\Delta_4 + \text{etc.}$$

$$(41) = a + 40\Delta_1 + 780\Delta_2 + 9880\Delta_3 + 91390\Delta_4 + \text{etc.}$$

For facilitating the computation, the binomial co-efficients together with their logarithms, belonging to each order of differences, are tabulated up to 80 terms. The solution of the equations may also be abbreviated, by choosing such terms, that the co-efficients in each equation will be multiples of 10, 100, 1000, etc.

If it is desired to set on the machine all the orders at the same time, it is necessary to make a further reduction of the quantities found from the equations. We prefer, however, to set them consecutively, after the computation has begun.

It is found, from our own work as well as that previously done with the machine, that it is occasionally liable to an accidental error, from the failure of one or more rings to perform its office. These errors are purely mechanical, and are not to be confounded with the principles on which the machine is constructed.

One of the first requisites is to hold the ring, on which the numbers are engraved, so that there shall be no side play, and yet allow it to move with the necessary freedom. The second is, to be able to destroy the momentum of the ring, as soon as the motive force ceases to act. The latter condition has been obtained by putting a "brake" piece on each ring, consisting of a small piece of leather or rubber pressed against its circumference, by means of a spring. The liability of accidental error would be greatly lessened by connecting ratchet wheels with each ring, so that it could only move in one direction. This would enable us to put more weight on the adding levers, without any danger of disturbing the position of the ring, when the motion of the shaft is reversed. A little attention to a few of these points would secure an almost perfect machine.

For bringing the type in line, previous to making the impression, we have employed a brass roller in place of the

wedge. This roller is pressed between the type by two ber wheels, and is found to work admirably. The type always straightened, no matter what their position may and without any possibility of injury to any part of the chanism.

Our past experience has led us to believe that such a e would be greatly enhanced in value, by the addi- one or two more orders of differences; since in that a much longer series of numbers could be computed one set of constants.

would be an easy matter to apply motive power to the chine, so that when once set, it shall be a complete autom- n, making its computations without the assistance of any person. As soon as one set of constants are exhausted, the machine will stop, and will also be made to give notice of the fact by ringing a bell; upon which, a new set of constants may be introduced, and the computations continued.

APPENDIX.

APPENDIX.

A.

AN ACT to incorporate the Dudley Observatory, of the city of Albany.

The People of the State of New-York, represented in Senate and Assembly, do enact as follows:

SECTION 1. Thomas W. Olcott, William H. De Witt, Ezra P. Prentice, Alden March, Joel Rathbone, Robert H. Pruyn, John B. Tibbitts, Ormsby M. Mitchel, Samuel H. Ransom, James H. Armsby, John N. Wilder, Isaac W. Vosburgh, Eliphalet Wickes, Stephen Van Rensselaer, and such others as they may associate with themselves, are hereby constituted a body corporate and politic forever, by the name and style of "The Dudley Observatory, of the City of Albany," for the purpose of establishing and maintaining an Astronomical Observatory in the city of Albany, and by that name they and their successors and associates shall be capable of taking, by purchase or otherwise, holding, conveying, or otherwise disposing of any real or personal estate, for the purposes of this incorporation, which estate shall not at any time exceed the net annual income of ten thousand dollars.

§ 2. The persons above named shall be trustees of the said corporation, and shall have power to fill any vacancies which may occur in their number, and shall have power to mak

such by-laws as may be necessary, and not contrary to law, relative to the management and disposition of the estate and concerns of said corporation, and to appoint such officers and servants as they may deem necessary.

§ 3. The said corporation shall be subject to the general provisions and liabilities, contained in the third title, of the eighteenth chapter, of the first part of the Revised Statutes.

OFFICERS OF THE BOARD.

THOMAS W. OLCOTT, *President.*
WILLIAM H. DE WITT, *Vice-President.*
JAMES H. ARMSBY, *Secretary.*
ISAAC W. VOSBURGH, *Treasurer.*

B.

DONORS OF ALBANY.

Blandina Dudley,	$76,500
Thomas W. Olcott,	11,000
John F. Rathbone,	5,500
William H. De Witt,	3,000
Stephen Van Rensselaer (Seven Acres of Land).	
Edward C. Delavan,	1,000
Ezra P. Prentice,	1,000
Henry Q. Hawley (Gas Works).	
Archibald A. Dunlop,	500
John Knower,	500
Alanson Sumner,	500
Robert Dunlop,	500
Robert Boyd,	500
John Taylor,	500
Marcus T. Reynolds,	500
Cornelius Wendell,	500
Samuel H. Ransom,	350
Isaac W. Vosburgh,	250
Robert H. Pruyn,	250
Joel Rathbone,	250
J. B. Plumb,	250
Wm. V. Many,	250
Eliphalet Wickes,	250
J. V. L. Pruyn,	250
John B. James,	250
John T. Norton,	250
Alexander Marvin,	250
T. F. and J. H. Humphrey,	250
Franklin Townsend,	200
Robert Townsend,	200
Gilbert C. Davidson,	160

James Stevenson,	$100
[illegible]nsing Pruyn,	100
[illegible]rles L. Austin,	100
[illegible]d H. Pease,	100
[illegible] Hawley,	100
[illegible]as Townsend,	50
[illegible]orn,	50

DONORS OF NEW YORK CITY.

[illegible]l A. Low,	1,000
[illegible]m B. Astor,	1,000
[illegible]ph Sampson,	1,000
[illegible]lantic Insurance Company,	1,000
James Brown,	1,000
George Law,	1,000
Grinnell, Minturn & Co.,	500
John C. Green,	500
James Boorman,	500
Goodhue & Co.,	500
George W. Blunt, (Astronomical Clock),	
Thomas Suffren,	500
Henry Chauncey,	500
Charles Butler,	500
Alexander Van Rensselaer,	500
Benjamin Brandreth,	500
Leonarda L. Suarze,	500
Sun Mutual Insurance Co.,	500
William Dennistoun,	500
Spofford & Tileston,	500
A. T. Stewart,	500
William Agnew & Sons,	250
[illegible]rtimer Livingston,	250
[illegible]mas C. Durant,	250

Richard H. Winslow,	$250
Phelps, Dodge & Co.,	250
M. Howland,	250
J. Boorman, Johnston & Co.,	250
Joseph Steele,	100
John J. Palmer,	100
R. Withers,	100
H. Q. Marquand,	100
William A. Booth,	100
J. E. Cooley,	100
Caleb Barstow,	100
George E. Pratt,	100
Jonathan Sturgis,	100
B. H. Field,	100
George Opdyke,	100
William Oathout,	100
Benjamin C. Lee,	100
John N. Genin,	100
Robert P. Colgate,	100
Howes & Co.,	100
H. W. T. Mali,	100
A. C. Richards,	100
W. T. Carey,	100
George T. Tremble,	100
Solomon Townsend,	100
W. C. Langley,	50
C. H. Sand, for the Ocean Steamer Co.,	50
C. J. & T. W. Goggell,	50
D. Capet & Co.,	50
Allen, Hazen & Co.,	50
N. Islin & Co.,	50
Ball, Black & Co.,	50
Slocumb, Stowell & Co.,	50

Marie & Kanz,	$50
Tifflin & Ironsides,	50
William Douglas,	50
F. Cottenet & Atherton,	50

DONORS.

John Greig, Canandaigua,	1,000
Garret Smith, Peterborough,	1,000
Alexander Duncan, Providence, R. I.,	1,000
Cyrus Strong, Binghamton, N. Y.,	1,000
B. A. Gould, Boston, Mass.,	500
Nathaniel Thayer, Boston, Mass.,	500
E. S. Prosser, Buffalo, N. Y.,	500
John McGee, Bath, N. Y.,	500
Robert Dunlop, Jamesville, N. Y.,	500
Marine Bank of Buffalo, N. Y.,	500
Elisha C. Litchfield, Cazenovia, N. Y.,	250
J. B. Lincoln, Boston, Mass.,	250
Mary Wigglesworth, Boston, Mass.,	100
Ann Wigglesworth, Boston, Mass.,	100
Wm. H. Swift, Boston, Mass.,	100
Martin Brimmer, Boston, Mass.,	100

Ellwanger and Barry, Rochester, N. Y. (shade trees).

C.

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D.

REPORT FOR 1862.

To the Board of Trustees of the Dudley Observatory:

The following is a condensed report of the work done at the Dudley Observatory, from the 1st of January to the 31st of December, 1862:

Number of Transits observed with the Olcott Meridian Circle,	863
Number of Zenith Distances,	1,445
Comet observations with Equatorial,	39
Zone Stars with the Declinometer,	1,087
Total of all kinds,	3,434

The Transits (with the exception of a few observations on circumpolar stars) were all observed by the magnetic method, the time being recorded on the Chronograph. In all of these observations, fifteen wires have been used.

In the reduction of all our observations we retain the hundredth of a second; and in certain delicate experiments, such as finding the difference between the rates of two or more clocks, we can readily measure an interval of time not exceeding the two-thousandth of a second.

From experiments made by recording observations on two chronographs at the same time, we find the error due to the irregularity of their motion, would never amount to more than the five-thousandth of a second of time, an almost inappreciable quantity, and one which may be safely neglected. Many interesting experiments have been made with this machinery, to determine the source of error in transit observations.

We have recorded, at the same time, the beats of three sidereal clocks; and by this means arrived at a knowledge of ...k's motion, which cannot be obtained in any other way.

The two Comets of this year were both independently discovered here by Mr. THOMAS SIMONS; the first on the 3d, and the second on the 18th of July. In the discovery of the first we were anticipated one day by the European Astronomers. The second was found on the same night at Cambridge, and three days before by Mr. SWIFT, an amateur astronomer of Marathon, N. Y.

The opposition of Mars during the present year has been decided as favorable for the determination of solar parallax. We have accordingly observed it with the Declinometer, on all possible occasions, from the 18th of August to the 1st of November.

The following Planets and Comets have been observed on the meridian:

(11) Parthenope.	From	July 25th to Aug. 19th.	No. Obs.	9
(39) Laetitia.	"	June 28th to July 3d.	"	4
(48) Doris.	"	July 25th to July 30th.	"	2
(55) Pandora.	"	July 25th to July 30th.	"	2
Comet I. 1862.	"	July 3d.	"	1
Comet II. 1862.	"	July 18th to Aug. 20th.	"	18
Neptune.	"	Aug. 21st to Dec. 31st.	"	38

The Zone observations, with the Declinometer, have been made, mostly for the investigation of the source and amount of error due to this method. From a comparison of the observations, with those made in the ordinary way, we find the probable error on a single observation, falls within the limits of accuracy usually assigned to observations made with the Meridian Circle. One great advantage lies in the fact that many bisections and readings can be made at the same transit, and in this way eliminating the ordinary errors of observation. You will understand the rapidity with which work can be done by this method, when I state that more than two hundred stars have been accurately observed in one

; and were they equally distributed, twice that number easily have been taken.

is instrument is one of the great inventions of our late l director, Prof. MITCHEL. From observations ring the last two years, and a careful discussion of m , I have arrived at the conviction that there is no wn method equal to it for rapidity and accuracy, aloguing of Stars.

observations have been made during the year with Meridian Circle, for the purpose of determining te places of standard Nautical Almanac stars. The so obtained have demonstrated the peculiar fitness of s instrument for delicate observation.

Time has been given to the city, by dropping a ball at the corner of State street and Broadway; the time signal being transmitted by passing the electric current through our mean time clock. In the Meteorological observations, we have read the barometer and thermometer twice every twenty-four hours.

All of the above observations, with few exceptions, have been made by myself, assisted in the reading of the declinometer and microscopes by Mr. THOMAS SIMONS, who is present in the evening.

G. W. HOUGH.

ALBANY, *January*, 15*th*, 1863.

REPORT FOR 1863.

To the Board of Trustees of the Dudley Observatory:

The following report will exhibit the nature and amount of the work done during the year 1863; as also the condition of the instruments, buildings, grounds, etc., at the beginning of the current year. It includes, moreover, such details

of the theory, construction and operation of the instruments in use, as well as of original investigations, and of methods peculiar to this observatory, as it is thought would be of interest to the donors and friends of the Institution, and not, perhaps, without value to the scientific world.

The buildings have been kept in good condition, by making a few necessary repairs as the occasion demanded. The apparatus connected with the shutters of the dome has been slightly altered, so as to afford greater facility in opening and closing them, and also greater security to the instrument during severe storms of wind and rain. A portion of the machinery for opening the West Transit room has been disconnected, making it much easier to handle, and less liable to get out of order. The grounds have been improved by the laying out of additional walks, and the planting of shrubs and trees.

The library, consisting of about 1,400 volumes and pamphlets, chiefly of a mathematical and scientific nature, has been enlarged during the year, by purchase and donations, to the extent of about 50 volumes and pamphlets.

The following Instruments have been in active use during the past year:

1st. The Olcott Meridian Circle, made by PISTOR & MARTINS, Berlin.

2d. The Transit Instrument, by the same makers.

3d. The Equatorial Refractor, made by Mr. FITZ, of New York.

4th. The Comet Seeker, made by Mr. CLARK, of Boston.

5th. The Declinometer, invented by Prof. MITCHEL, and made by Messrs. FOSTER & TWITCHELL, of Cincinnati.

6th. The Charting Machine, made by Mr. FASOLDT, of Albany.

7th. The Sidereal Clock, No. 1, movement by DENT, pendulum applied by BOND & SON, of Boston.

8th. Sidereal Clock, No. 2, by HOWARD & Company, of Boston.

9th. Chronograph, invented by Professor MITCHEL, made by FOSTER & TWITCHELL, Cincinnati.

10th. Barometer, by FASTRE, of Paris.

We have also a magnetic Mean Time Clock, by Mr. FARMER, of Boston; Chronometer, by JOHNSON, of London; Clocks for the Observing Rooms, and other minor apparatus needed or useful in an observatory.

The New Transit Instrument, made by Messrs. PISTOR & MARTINS of Berlin, was mounted in the month of January.

This Instrument is one of the first class, and in its principal features is similar to the Olcott Meridian Circle. The focal length is 8 feet, and the object glass of 6⅜ inches clear aperture. It is provided with two circles, which are two feet in diameter, and are constructed on the plan best adapted to secure permanence of figure. The radii, or spokes, are in the form of a triangular prism, which gives the greatest strength with the least expenditure of metal.

As it was originally intended to attach the Declinometer apparatus to this instrument, one of the circles is undivided, and the other only divided to single degrees. If it should ever be deemed advisable to complete the divisions, we would have in it an admirable Meridian Circle.

The method of illumination is similar to that of the Olcott Meridian Circle, with the exception that in the place of one screw-head at the eye end, we have two. By means of these, the degree of illumination can be graduated with the nicest precision.

The instrumental errors are determined in nearly the same manner as for the Meridian Circle. The level and collimation errors are found by reversed positions of the instrument when directed to the nadir. The level and azimuth of both instruments are determined every morning, the former by the spirit-

level, the latter by directing the telescope to the meridian mark, and measuring with the micrometer the deviation of the middle wire; which, being freed from the collimation error, gives us the azimuth. These azimuthal determinations are not used directly in reducing observations. They serve, however, to show the variation of the azimuth from day to day, and are a valuable check on the elements of reduction. For, if we have found the difference of azimuth between the two instruments constant, or nearly so, for a number of consecutive days, we ought to get the same result from the observation of a circumpolar star.

We have examined, to some extent, the form and size of the pivots. From numerous observations, made with two spirit levels hung on the axis in reversed positions of the instrument, the difference in the size of the pivots is found to be inappreciable. We have been unable, in the use of the spirit level, to detect any ellipticity in the shape of the pivots; but when our transit observations, made with both meridian instruments at the same instant, are fully reduced and discussed, we expect to be able to determine the form of the pivots for both instruments.

An account of the method employed in mounting the Transit is appended, as a matter, perhaps, of professional, if not of general interest.

It was assumed as the basis of our plan, that the Telescope should, as far as practicable, determine its own position. A great deal of unnecessary labor was thus avoided, and great precision was insured in the position of the Ys. The telescope, having been lifted out of its box, was placed on the reversing apparatus. The object glass was then screwed in its cell, and the Telescope moved between the two piers, when it was directed to a meridian mark six miles distant. The value of the micrometer screw was now

approximately determined, by measuring the angular distance between two distant objects; which had previously been done with the micrometer of the Olcott Meridian Circle. Knowing the azimuthal angle between the Meridian Circle and the Transit, the new Telescope was at once set in the true meridian, and vertical lines were drawn on the stone piers at the opposite ends of the axis. With an ordinary straight-edge level, I found approximately the plane of level between the two piers.

The place for one Y was then marked out on the stone, and the telescope being removed, the workmen began cutting a cylindrical hole to receive the Y piece. When one pier had been perforated, the Y piece and the tube were inserted; the counterpoises were placed temporarily on the piers, and the telescope was again brought into position; the other Y being attached to a board temporarily fastened to the pier. The reversing apparatus being removed, the level was hung on the axis, and the telescope was brought exactly level in its own Ys. It was also directed to the meridian mark, and brought in the true meridian; after which it was removed, and a fine dot made on the pier, showing the centre of the Y piece. A circle being described about this as a centre, we had the absolute direction of the axis. It only remained now to cut a hole as nearly perfect as possible. This was successfully accomplished by Mr. ROWLAND, of the firm ot BROOKSBY & ROWLAND.

When the Y pieces were slid into these holes without cement (for they were made to fit exactly), the level error was found to be zero and the azimuth 8 seconds. This corresponded to an error in the position of the hole of less than the two hundredths of an inch. Had the workmen cut the cavity for the second Y as originally marked on the stone, the telescope would have been absolutely in position.

The use of a meridian mark or of another instrument is not, however, essential to this method; for in the absence of these, we would determine directly from observation, the position of the instrument after one Y had been fitted in its cavity.

Observations made with the Olcott Meridian Circle.

Number of transits, 15 wires each, ... 953

Number of zenith distances, ... 639

The transits comprise Nautical Almanac stars, Standard Zone stars, Planets and Comets.

The following is a list of the Asteroids and Planets observed during the year:

(1)	Ceres.	From	Aug. 26th to Oct. 13.	No. obs.	16
(2)	Pallas.	"	Aug. 24th to Sept. 2d.	"	3
(5)	Astrea.	"	March 19th to April 14th.	"	6
(8)	Flora.	"	Sept. 9th.	"	1
(9)	Metis.	"	June 13th to June 17th.	"	3
(19)	Eunomia.	"	April 27th to May 1st.	"	2
(20)	Massalia.	"	Aug. 27th to Sept. 16th.	"	8
(21)	Lutetia.	"	Aug. 27th to Sept. 9th.	"	6
(51)	Nemausa.	"	Sept. 15th to Sept. 30th.	"	8
(64)	Angelina.	"	Oct. 17th to Oct. 29th.	"	3
(65)	Cybele	"	Sept. 7th to Sept. 30th.	"	8
(79)	Eurynome.	"	Sept. 23d to Nov. 19th.	"	14
	Neptune.	"	Sept. 7th to Jan. 2d, 1864.	"	29

For our list of Clock stars, we have used the English Nautical Almanac, with the corrections given by the Greenwich Observations. After August 27, we used the corrections given by Mr. Safford's Memoir on Clock stars.

The number of transits observed with the Transit instrument, 15 wires each, is 796. These are mostly on the standard Nautical Almanac stars.

The observations with both Meridian instruments are made by the chronographic method, using two sidereal clocks, one of which makes a record every two seconds. The other is recorded at the end of every half hour during the continuance of the observations. By this plan, any change of rate in the former during the time of observation is detected by comparison with the latter.

In Zenith Distance work, direct observation is preferred to the method by reflection from a surface of mercury, the latter being seldom employed. The nadir point is found by observing the reflection of the wires seen in a basin of mercury, placed underneath the centre of the telescope. This can be done with the collimating eye-piece, or with the ordinary observing eye-pieces, by placing over them a cap, having a piece of plane glass set at an angle of 45° to the collimating axis of the telescope.

During the passage of a train of cars around the foot of the hill, the surface of the mercury is agitated to such an extent as to render observations for nadir impossible. This is annoying, in so far as it occasions a brief delay of the observation, which can, however, generally be avoided by selecting a time free from such disturbance. So far as we have determined, no evil effects result from this tremor. The nadir point itself, as well as the level and azimuth errors are as constant as for any instrument of which we have the published records. We propose, however, to support the basin of mercury with India rubber springs, in a manner similar to that recently adopted by Prof. AIRY and Capt. GILLISS, which we believe will enable us to observe the nadir point at any time without trouble.

The Equatorial has been used for the observation of planets, and occultations of stars by the Moon.

It has, however, been principally employed, usually under

the direction of the Janitor, in exhibiting objects of general interest to visitors.

The plan here adopted of admitting visitors under certain restrictions, is found to occasion but little practical inconvenience. It tends, at least, to the dissemination of much useful information, and will doubtless promote a more general study of the science, and a better understanding of its fundamental principles. The interest manifested by the public in astronomical matters, seems, indeed, to be on the increase from year to year. The Observatory has been visited during the year by more than one thousand persons, citizens and strangers.

The Comet-seeker has been used occasionally by Mr. SIMONS in searching for comets. Owing to our limited force, but little time has been given to this kind of work.

Our zone work has been confined to the cataloguing and charting of a zone of stars lying between the Equator and 10′ of south declination. Forty zones have been observed, comprising 6,000 observations, being an average of 150 stars per hour. As many of these zones were observed when the Moon was near the meridian, the number of stars seen is not as great as it would otherwise have been. Our scale of magnitudes will not differ much from that adopted by Prof. BOND, in the Harvard zones of 1852-1853.

In the greater portion of our zone work during the year 1863, we have used only one wire for right ascension. A comparison of duplicate zones observed during the year showed that the probable error in right ascension, using one wire, was, when reduced to arc, about the same as that found from the declinations. Wishing to determine this ordinate more accurately, we have latterly used two wires; setting for this purpose the vertical movable wire of the Olcott Meridian Circle micrometer at an interval of two seconds from the fixed

wire, and thus obtaining much better results in right ascension, with but little additional work. For the declinations, when the stars are not very numerous, we make two or more bisections and readings during the transit of the zone. Standard stars are usually chosen preceding and following the zone, and are observed on 15 wires in right ascension, and with from 10 to 15 bisections and readings in declination.

As we have undertaken to include all stars fairly within the capacity of our instrument, the limit of error on those of the highest magnitudes, as might be expected from their extreme faintness, number, and inequality of distribution, is materially increased, although by no means to a degree impairing the value of the work, as may be seen from the following results:

	A. R.	DEC.
Probable error of 1 obs. 9th mag. to 12th mag.,	$\pm 0^s.06$	$\pm 0''.80$
" " 13th " 14th "	± 0.13	$\pm 1''.50$

The results from the use of two right ascension wires are more satisfactory, as is shown by the following:

	A. R.
Probable error of 1 obs. 9th to 12th mag., inclusive,	$\pm 0^s.04$
" " 13th to 14th "	$\pm 0^s.11$

The comparison of the charts with the declinometer results, gives, for the probable error in the position of any star on the chart, a little less than the one-tenth of a minute of arc. The magnitudes are recorded by the use of different colored sheets of impression paper. These charts, after the zone is observed, are marked and filed, for future use or reference; any remarks which may have been made, being noted on the border. They are found to be of great assistance in detecting accidental errors of minutes, without the necessity of re-observing the zone; for the comparison of the chart with the scale readings will at once show whether a wrong minute has been entered on the records.

When duplicate zones have been observed, the two charts are carefully compared, and any discrepancies noted.

The Sources of Error in Transit Observations.

This subject is one which presents many difficulties, and requires a long series of observations to determine with any degree of satisfaction, all the sources of error. The probable sources of error will be enumerated; after which will be given the results obtained, so far as we have been able to investigate the subject.

1st. Personal Equation. By this error is meant the variability of this element during the time of observation, as well as the variable personal equation for different declinations.

2d. The Clock error, due to irregular rate during the day of observation.

3d. The Personal error, for inaccurate observation.

4th. The error due to the chronographic method, including armature time, irregularity in the clock records, and irregular motion of the Chronograph.

5th. The errors due to the instrument, including the errors of level, azimuth and collimation. These may be divided into two classes: 1st, Inaccurate determination of these quantities; 2d, The variations of these quantities during the time of observation.

6th. Errors due to the atmosphere, chiefly caused by unequal temperature of the observing room and the outside air.

7th. Form and size of the pivots, including inequality of pivots as well as want of cylindricity.

During the year, some attention has been given to the subject of personal equation, and a number of experiments have been made to determine the limit of error from this source.

For this purpose, a series of 25 vertical pins, placed at intervals of about 2 seconds of time, was fastened in the rim

of the revolving disk of the Chronograph. By the revolution of the disk, these pins were made to pass in front of a zero point. One of the collimator telescopes was placed at a distance of 20 feet from the disk. The power of the telescope was such, that the pins seemed to move with the apparent velocity of an equatorial star observed with a power of 800. The person observing held a magnetic make-circuit key in his hand; and as the pins passed this point, he made a record on the chronograph. After this was done, the pins were made to record their own time of transit, by causing the circuit through the magnet to be closed when they were exactly in front of the zero. By making a few records before and after the observations, the points of absolute time when the pins made the transit were found. By drawing radii through these points, a standard was obtained from which to determine the absolute personal equation of each observer.

To determine the armature time of the helix, after the pin had recorded its own transit, the disk being in motion, the same apparatus was made to give a record, by moving the disk gently, and stopping it at the transit of the pin.

The difference of personal equation between two observers is found to be less, when the pins are observed, than when stars are observed with a power of 100. It is also found by this method, that it varies in a measure, with the magnifying power used.

From this we conclude that personal equation depends, to a great extent, on the apparent motion of the star as seen through the Transit telescope; and with the same power, the personal equation of an observer will not be the same for an Equatorial star, as for one near the Pole; and will, of course, be a variable quantity between the limits of the Pole and the Equator.

It is not assumed, however, that this point can be as yet

regarded as established beyond question; although, should the principle be proved correct, it may perhaps account for some of the anomalies in transit observations.

We have found from these experiments, that the absolute personal equation was not liable to any very large variation; yet in order to eliminate as much as possible this source of error, we have adopted it as a rule, not to use the observation of one person to determine the clock error, for the observation of another.

The clock error may be eliminated by using two or more clocks, in the manner before stated.

The personal error is constant, or nearly so, and for an equatorial star, amounts to $0^s.025$ for a single wire.

The errors due to the chronographic method may be regarded as of a very low order, and will not affect the observation to any sensible amount.

It has been intimated by a recent writer on the subject, that the armature time for the make-circuit is liable to great variations; but this does not accord with our experience. It is found from experiment with our recording pens, that the difference between the armature time of the same pen, whether the circuit is a "make" or a "break," is only $0^s.01$ in favor of the break-circuit.

The mean value of the armature time for one pen is $+ 0^s.05$; and this value is not liable to an appreciable variation during a night's work, so that the error from this cause may be regarded as insensible.

The errors due to the instrument: The collimation error may be accurately determined, and, for a first-class instrument, is constant for long periods of time. It will not, therefore, introduce any appreciable errors in the observations.

The level error cannot be accurately determined by the spirit level; and even if found by different methods, it is not permanent for any considerable period, neither does it change proportionally to the time. We believe the changes are sudden, or accidental. For our meridian instruments, the change from day to day is small, the variation for two or three consecutive months sometimes not amounting to more than 1″ of arc. Although the same level is found (within the limits of error of determination) for three or four consecutive days, yet on the next day it may have changed 1″, which cannot be due to inaccurate determination; and, again, on the subsequent day and a number following it, it will return to its original value.

The error of azimuth is liable to error in its determination, and is not constant, the change being analogous to that of level. Through the kindness of Mr. EDMUND BLUNT of Brooklyn, we have a permanent meridian mark, distant a little more than six miles. This affords an admirable check in azimuth determinations.

The errors due to the atmosphere are considerable, and cannot be wholly avoided. Much, however, will be gained by reducing the temperature of the observing room to the same degree as that of the outside air. The nearer this condition is fulfilled, the better will be the observations. In the summer season, in a room properly constructed, this condition can generally be secured.

In the determination of personal equation, it was stated that a number of artificial stars were made to record their own transits, and were also recorded by the observer. In this case there was no atmospheric disturbance to affect the stars, and whatever error there might be was due to inaccurate observation. The mean error for a single wire was found to be $0^s.025$; for 5 wires, $0^s.014$; for 20 wires, $0^s.005$.

From a comparison of the mean of 5 wires with the mean of 15 wires, on 600 observations made in 1862, taking them in order from the transit records, it was found, for an equatorial star, that this difference amounted to $0^s.035$. For the same stars, the difference between the middle thread and the mean of the fifteen reduced to the middle, amounted to $0^s.07$. By comparing these results with those obtained from observations of artificial stars, we conclude that the great source of error in recording transits is due to atmospheric disturbances; the error for artificial stars being only about one-third as great as for observations made in the ordinary way.

The accuracy with which a transit is recorded will in a great measure depend on the number of wires used. Our observations on artificial stars show, that the personal error is very small, and under favorable atmospheric conditions, five wires would be amply sufficient for any class of observations. But as there are but few excellent observing nights in a year, in order to secure the same degree of accuracy on ordinary occasions it is necessary to increase the number of wires.

We may here remark that there is a difference of opinion among astronomers in regard to the number of wires to be used; the number employed varying from five to twenty-five.

A recent writer on this subject has shown by computation that the final right ascension deduced from the transit over 5 wires is nearly equal to one over 25 wires, or any greater number. In case the conditions of observation were always the same, this result might be regarded as settling the question. But obviously so many varying circumstances must be taken into account, that it becomes a difficult matter to decide in how far the application of theory may be correct.

In deciding on the number of wires to be used, we ought to be guided, first, by the quality of the instrument used; second, the kind of work which is to be done. In case

inferior instrument is used, in which the uncertain instrumental errors may at any time amount to $0^s.10$, it would be a useless waste of time and labor to observe on more than two or three wires. But with a first class instrument, where the uncertain instrumental errors will always be small, and for special kinds of work may be regarded as wholly eliminated, it is desirable to reduce the observation errors to the smallest possible limit.

For instance, in a series of observations on an asteroid or planet, where the object is at once compared with stars preceding and following, lying on nearly the same parallel of declination, the uncertain instrumental errors may be regarded as insensible on the result. In this case, much better places can be deduced by using a large number of wires. In asteroid observations with a meridian instrument, the object is usually faint and difficult to observe; and in order to secure the same degree of accuracy as for an ordinarily bright star, it is necessary to increase the number of wires.

The errors due to form of pivots will depend on the quality of the instrument used. In a first-class instrument, the errors arising from this cause will be small, and not easy of detection by direct observation, unless all other sources of error have been well determined.

By using two meridian instruments at the same time, this error may perhaps be determined with some degree of accuracy. It is by this means also that the total effect of all errors, which are not eliminated by the method of observation, may be found.

Suppose, for example, we have two meridian instruments of equal value, and make a series of simultaneous observations on the same stars separated by 5° or 10° of zenith distance. By the comparison of these observations, the errors due to the chronograph and clock are eliminated, as also those due to the atmosphere.

The error of collimation we regard as eliminated. There remains then for discussion the error of level and azimuth, form of the pivots and personal equation; or if we regard the last as constant, only the level and azimuth, and inequality of pivots. From a comparison of stars near the horizon, it may be determined how much of this error is due to azimuth; and by stars near the zenith, how much is due to level; assuming, in the first place, the error of pivots: zero. By correcting for these errors, and comparing the whole series, we may arrive at some conclusion with regard to the form of the pivots; and by using the instruments in a reversed position, on a subsequent night we may decide how nearly our results are correct.

The Compensation of a Pendulum by the use of the Chronograph.

Nothing is perhaps more desirable to the practical astronomer than a clock, which can be relied upon to keep its rate within certain limits; for with an imperfect and irreliable clock, the best transit instrument is rendered almost useless for fine observation.

It is a difficult matter to find a clock that is correctly compensated for the ordinary range of summer and winter temperature in this climate. The method generally used by makers, for the compensation of a pendulum, can only insure approximate results; and it is not unusual to find a daily variation of two seconds between the summer and winter rate. The question then arose whether any expeditious plan could be used, which would with certainty indicate whether the pendulum of a clock was correct for the ordinary range of temperature. This has been successfully accomplished by the use of the chronograph.

The following is the general plan adopted: The pendulum to be compensated, together with the movement, was

put in a closet temporarily built for this purpose. When set in motion, its rate, compared with that of another clock, was determined by recording the oscillations of both on the chronograph for an hour or more. The temperature was then noted, and heat applied so as to raise the temperature in the closet about 50°. During the process of heating, the oscillations of both pendulums were recorded on the chronograph. The heat being raised to the proper degree, was kept at this point for two or three hours. Thermometers placed near the top, bottom and middle of the pendulum, were read every five minutes. With a mercury pendulum, it was found that during the process of heating, the experimental clock lost on its rate, no matter what the want of compensation might have been, owing to the fact that the rod was affected sooner than the mass of mercury comprising the "bob."

On comparing the rates, given in the two temperatures, the want of compensation was at once detected. To guard against error from any accidental disturbances, the operation was repeated; and if the results agreed, the experiment was considered satisfactory.

After adding or subtracting any convenient amount of mercury, *e. g.*, 8 ounces, as the results might indicate, the same process was repeated; and having determined the effect of this amount of mercury in the compensation, it was easy to calculate approximately the amount of mercury to be applied to the pendulum in its original state. By continuing this process, the compensation of the pendulum was determined for the range employed. After this has been decided as satisfactory, we may test the compensation for any intermediate temperature, and determine the temperature constant.

The time required for making an experiment is about 3

hours for the first; and a small increase in the time as the compensation is more nearly perfected. Three or four repetitions will give an excellent pendulum.

For some of our experiments, we have used the natural temperature of the air. Placing the clock in a small room, heated by the furnace, the temperature of the room is raised for the middle of the pendulum to 60°. Finding now the relative rate of the clocks, the furnace is shut off and the room opened, reducing the temperature to 10°; when the experiment is conducted as before. This method is susceptible of much more accurate results; since a more uniform temperature is maintained, and the pendulum is not liable to disturbance from currents of air, as may be the case in applying artificial heat. By the use of the chronograph in this method, we are able to appreciate much smaller intervals of time, and can, by repeating our experiments a sufficient number of times, produce an almost perfect pendulum. Besides, the ordinary range of summer and winter temperature is sufficient for securing the compensation; for, with this apparatus, hundredths of seconds are certain quantities. During the process of the experiments, we record the difference of rates from second to second and minute to minute. If they extend over any length of time, two or more standard clocks may be used for comparison. This has been done in our experiments, the second clock being recorded every 30 minutes.

During a portion of the night of August 10th, a series of observations was made, in concert with observers at other stations, to determine the position, direction, and time of flight of all meteors in the portion of the heavens under examination. Before commencing our observations, a wire and observing key were carried outside, so that the time of

appearance and duration of flight could be recorded on the chronograph. We believe this is the first attempt in the United States, at least, to observe by this method the duration of flight of a meteor.

From the records of 9 meteors observed by Mr. THOMAS SIMONS, the mean duration of flight was found to be 0ˢ.29. From my own observations on 7 meteors, it was 0ˢ.55; the maximum and minimum duration of flight being respectively 0ˢ.66 and 0ˢ.22. Mr. SIMONS recorded some that were very small, whereas my own observations were confined exclusively to the brighter ones; which will explain the difference between the two results.

If the time of appearance should be accurately recorded at two stations, and the apparent path noted, it would be of great assistance in determining the distance and velocity of these bodies, and aid much in developing the true theory of their origin.

Were observations of this kind made at two or more stations at which the same meteor would be visible, one night's work would give an accurate determination of the difference of longitude between the stations.

During the year a Time Ball has been dropped every day at noon, at the corner of State street and Broadway; the time signals being transmitted by passing the electric current through our mean time clock, especially arranged for this purpose. The N. Y. Central R. R. has also been supplied with the correct time, through Mr. BENJ. MARSH, who has charge of the time ball.

Our effective working force has always been small, and inadequate to the instruments. During the year, Mr. THOMAS SIMONS has assisted in the evening; his work being mostly confined to reading the declinometer for zone observations.

He has also occasionally made observations with the meridian instruments, when not engaged in searching for comets.

The two young assistants, Messrs. McClure and Foreman, have assisted in the meridian observations, and have been employed in measuring up the chronographic records, and in the reduction of observations.

The duties of the Janitor consist in keeping the Meteorological Records, waiting on visitors, and keeping the buildings and grounds in order.

G. W. HOUGH.

Albany, *February* 1*st*, 1864.

REPORT FOR 1864.

To the Board of Trustees of the Dudley Observatory:

The following brief report will exhibit the nature and amount of work done during the year 1864:

Number of Transits observed with the Olcott Meridian Circle,	785
Number of Transits observed with the Transit Instrument,	325
Number of Zenith Distances,	750
Number of Zone Observations made with the Declinometer and Charting Machine,	2,000
Total,	3,860

In the transit observations made with both meridian instruments, fifteen wires have been used, and the times recorded by the chronographic method.

The past year has been unusually unfavorable for observations. During the spring and winter months we have had a

great deal of cloudy weather, and during a portion of the summer the atmosphere was so charged with smoke and fog, as to prevent observations on any other objects except the brighter class of stars. This peculiar state of the weather was not confined to one locality, but seems to have been general throughout the United States.

At the beginning of the year, by request of Capt. GILLISS, Superintendent of the United States Naval Observatory, we selected six of the minor planets for observation at this Observatory. It has frequently been proposed by astronomers to make a division of labor for the observations of these small bodies; and Capt. GILLISS, in behalf of the United States, has undertaken the observation of a portion of them. Of the six which we agreed to observe, one could not be found, although the region in which it was supposed to be was charted over a number of times. It was situated in a portion of the heavens very unfavorable for detection, since we found so many small stars, even in a zone of ten minutes in width, that it was almost impossible to chart them all. The probabilities are that the Ephemeris was largely in error.

The following were observed with the Olcott Meridian Circle:

Astrea.—Seven observations, from June 29th to July 30th.

Victoria.—Fifteen observations, from June 29th to September 10th.

Eunomia.—Twelve observations, from June 29th to September 10th.

Psyche.—Ten observations, from July 12th to September 1st.

Ariadne.—Six observations, from S[illegible] to October 4th.

The Ephemeris for Ariadne was in error over 3′ in Declination, and it was found on the meridian, by charting two short zones on the evenings of September 19th and 20th.

In my previous reports I have spoken in detail of our method of charting stars. The more we have used it, the more we are convinced of its great value for certain kinds of work. Indeed, so far as we know, no other method has been devised that will give us a chart of stars with the same degree of rapidity and accuracy.

The Scheutz Calculating Engine has been used for computing approximate Ephemerides of the small planets, and for this kind of work has been found of considerable value.

We have added a new and simple apparatus to our mean time clock for the purpose of giving time signals. It has been found to answer the purpose better than any method we have before tried. The time signals are given every minute throughout the day to Mr. Marsh, corner of State street and Broadway, who has charge of the time ball, which is dropped every day at noon. The New York Central Railroad has also, through him, been supplied with the correct Observatory time.

During the year we have made a slight, though, we believe, an important change in the Declinometer apparatus. We have before stated that the chief source of difficulty with this mechanism lay in the change of the length of the connecting rod, from the effect of temperature. We have, therefore, abandoned its use entirely. By this change we get rid of one joint altogether, and another is improved by the change. In the place of the glass connecting rod, we have attached a solid arm of wood, so that it becomes part of the long arm itself. To the end of this is fastened a steel knife edge, [illegible] cylindrical groove, placed at the extremity of [illegible] the reading telescope, which is now [illegible] so counterpoised that it

presses against the knife-edge with a force of about two ounces. It is found that with this arrangement, we get less change of position from temperature, and much greater stability in the apparatus. In fact, so stable is the mechanism in this form, that on removing the reading telescope and again replacing it, the scale of reading is not changed an appreciable amount, a result which before it was almost impossible to attain.

But few observations have been made in the cataloguing of zone stars, owing chiefly to the unfavorable condition of the weather. We have recently adopted the plan of observing zone stars on five wires in right ascension. A method for regulating the amount of illumination for zone work and Asteroid observations has been perfected during the year, so that it is in the power of the observer to instantly shut off all the light or any portion of it. That we may be understood, it would be well to state that the Olcott Meridian Circle is arranged with a screw at the eye end for regulating the amount of the illumination. In the use of this in zone work, too much time is lost, besides both hands of the observer are constantly employed in the manipulation of the other mechanism, so that it is impossible to change the illumination rapidly enough. But with the additional apparatus, the observer instantly secures the proper amount of illumination, without interfering with his other duties.

The planet Neptune has been observed on all possible occasions. On the 30th of November, a drawing was made of the planet Mars, which at that time presented a peculiar appearance. The definition was sharp and well defined, and the surface of the planet had the appearance of a large continent somewhat resembling Africa.

The Dome for the Equatorial has been repaired, so that it moves with much greater freedom than formerly. The

buildings and instruments have been and are in good order. During the year, Mr. THOMAS SIMONS has assisted in the evening; and the two young assistants, McCLURE and FOREMAN, have been engaged in computations, and have also assisted in the observations. The janitor has attended to the ground and buildings, and has also kept the meteorological records, and waited upon visitors in the evening.

G. W. HOUGH.

ALBANY *January 3d*, 1865.

REPORT FOR 1865.

To the Board of Trustees of the Dudley Observatory:

The following brief report will show the nature of the work done during the past twelve months, as well as the condition of the buildings, instruments, etc., at the beginning of the current year.

The grounds and buildings remain nearly the same as at the last report. Some necessary repairs have been put on the dwelling-house and observatory as the occasion demanded, and we believe they are now both in good condition The Equatorial dome, since the changes and repairs of last year, has worked much easier and in every way more satisfactorily. The foundation does not appear to have been disturbed by the constant use of the instrument during the past six years, and the balls and frame work are but little worn.

The driving clock for the Equatorial was repaired and slightly changed in some of its parts, and is now found to give better results than formerly, still as it is defective in the principle of construction, it does not give entire satisfaction. As soon as our time will permit, we propose adding an at-

tachment which it is believed will regulate the motion more accurately. The parallel wire micrometer has also been repaired and new systems of wires inserted suitable for observations by the magnetic method.

The Equatorial has been employed occasionally for extra meridian observations on planets and nebulae; and when not needed for scientific research, it has been used, usually under the direction of the Janitor, in exhibiting objects of interest to visitors. The annular solar eclipse of the 19th of October was observed, but owing to the cloudy state of the weather, the results were not of much value.

The Olcott Meridian Circle has been in constant use in the observation of standard stars, zone stars and the small planets. It is our purpose, as soon as possible, to complete our zone work extending from 0′ to 20′ south declination and from 0^h to 24^h A. R., and prepare it for publication. We have now on hand more than 10,000 zone observations which are partially reduced, but owing to other pressing duties of the past year and our small working force, we have not been able to make much advance in their complete reduction. Our method of observing zone stars, the details of which I have given in former reports, is peculiar to this observatory, and is believed to be as expeditious as any method in use.

The planet Neptune has been observed as on former years on all possible occasions, from September 29th to December 16th. Meridian observations have also been made on six of the minor planets.

In the month of March I concluded to test by actual experiment an idea long entertained, of causing any moving body or medium, to *record* and *print* its changes automatically, by means of electrical agency. The barometer was the instrument chosen for this experiment. The problem to be solved was this: to cause a machine to follow the motion of

the mercurial column, with force sufficient to make a legible and printed record, without deriving this power or force from the column itself. This method of electrical contact is entirely new, and so far as we can learn, nothing of the kind has ever before been attempted. About the 1st of April, three weeks from the perfecting of the idea, a mechanism hastily constructed from a couple of clock movements which we happened to have at hand, proved beyond a doubt that the method could be made eminently practical in the recording of Meteorological phenomena generally. After being tested for a few days, the instrument was taken down and the printing portion added, since which time it has been in constant use, in recording the barometric pressure and printing the hight hourly to thousandths of inches.

The discussion of three months of observations by this method gave the tropical hours of diurnal maxima and minima in a very satisfactory manner, showing conclusively the peculiar fitness of this method for delicate observation. These results, together with other matters on the same topic, have been published in the January number of "The American Journal of Science."

During a portion of the months of September and October, at the solicitation of scientific friends, we placed the apparatus at the fair of the American Institute, held in New York City. It is needless to say that the method commanded the attention of meteorologists and scientists generally. On its return from New York, it was again mounted in the observatory, where it has continued to record and print the barometric changes without the failure of a single hour, with the exception of one day in November, and one in December, when its action was interrupted to make some experiments with different forms of mechanism.

It would require too much time and space to speak in

detail of the results already attained by the use of this method; they will, however, be given to the public, as fast as they are confirmed. It is our intention to test thoroughly the value of the barometer as a weather indicator. Although this instrument has been in use more than 200 years, yet but few laws of atmospheric phenomena, as applied to the weather, have been established. We believe this is not so much the fault of the instrument as the manner of using it. The experience of only a few months has led us to surmise, that the fluctuations of the barometrical column have an important bearing when taken in connection with the hight and general motion. We have accordingly, recently attached an additional apparatus for counting and recording all the pulsations of the atmosphere, which are of an amount sufficient to cause a change of one-thousandth of an inch in the pressure. It is a noticeable fact with us, that previous to, and during great storms of wind, the barometer oscillates almost continually, and we are led to believe that the magnitude and violence of the storm, will, in a great measure, depend on the number of oscillations, as compared with the rise or fall of the column. It would, however, be premature to attempt to prove this theory from the few storms which we have observed.

We purpose, as soon as convenient, to apply this method to the registration of the velocity and direction of the wind, the record of temperature and the fall of rain.

Donations to the library of books and pamphlets have been received from the following institutions and individuals.

Royal Observatory, Upsala, Dr. GUSTAV SVANBERG and Dr. H. SCHULTZ.

Professors E. PLANTAMOUR and A. HIRSCH, Geneva and Neufchatel.

Royal Observatory, Greenwich, Prof. G. B. AIRY.

Dr. C. Bremiker, Berlin.

Prof. Joseph Winlock, Supt. Amer. Naut. Almanac.

Royal Observatory, Edinburgh, Prof. Charles Piazzi Smyth.

Observatory, Breslau, Dr. J. G. Galle.

Observatory, Utrecht, Prof's M. Hoeck and A. C. Oudemans.

Prof. E. L. Seezen, Riga.

Admiral W. H. Smyth, London.

Cambridge Observatory, Eng., Rev. James Challis.

Observatory, Copenhagen, Prof. H. C. F. C. Schjellerup.

Royal University, Norway, H. Mohn, G. O. Sars.

M. Pierre Beron, Paris.

Royal Observatory at Pulkova, Prof's O. Struve, A. Winnecke, W. Dollen, Carl Linsser, H. Gylden, A. Wagner.

Radcliffe Observatory, Rev. Robert Main.

Hon. Ira Harris, Washington.

U. S. Naval Observatory, Rear-Admiral C. H. Davis.

Harvard College Observatory, Prof. T. H. Safford.

Dr. F. B. Hough, Albany.

Nicholas-Head Observatory.

Prof. F. M. Karlinski, Observatory of Cracow.

Bureau of Navigation, Washington.

During the year, over one thousand persons, citizens and strangers, have visited the observatory. About the 1st of July last, Mr. Thomas Simons, who has given us a portion of his time during the past four years, removed from this city. He is deserving of our thanks for the zeal and interest manifested in the cause of astronomical science. Mr. Thos. E. McClure still continues as the regular assistant. Our effective working force has always been too small to accomplish all that we desire, and we have accordingly been

E.

OBSERVATIONS OF THE PLANET MARS, MADE AT THE DUDLEY OBSERVATORY, 1862.

The Mars Observations were made with the Olcott Meridian Circle, using the declinometer for the observations on the planet itself. During the passage of Mars we placed the micrometer thread alternately tangent to the upper and lower limbs of the planet, reading from our declinometer scale the seconds and fractions; the limit of error for a single reading being about two-tenths of a second. We always made at least three bisections of each limb, and sometimes six, the average being about four. Immediately before and after the transit of the planet, the declinometer scale was compared with the circle; the difference between the two comparisons being usually within the limits of reading, and rarely amounting to 0″.5. In every case we have used the mean of all, corrected for the runs of the scale, which have been assumed constant throughout the whole series. The comparisons were generally made at a point on the scale corresponding to the reading of Mars' centre, thereby eliminating the error of runs entirely.

At the time of these observations the declinometer reading telescope was not mounted as firmly as it should have been, and to this cause we attribute the greatest source of error. It was mounted on a stand connected with the east pier of the Olcott Meridian Circle by means of ¾ inch iron rods about 10 inches in length. It was found on pressing with some force (*e. g.*, 10 lbs.) on this frame, that the position of the reading telescope could be changed on the scale 2″ or 3″, and any greater or less amount of pressure would change the position in a proportionate ratio.

It may be proper to remark, that after applying the pressure to the reading telescope support and causing it to change the scale reading, on removing the pressure it would take up its original position, the limit from many trials being 0″.5. In case, however, the support was not disturbed during the time of observation, this source of error would not be appreciable. We were always particular that this should be the case, still it may at times have been accidentally disturbed, but we find no record of this kind in the Mars series.

This trouble has since been removed by bolting a solid oak block against the surface of the pier, so that any force a person may apply to it will not change the position of the reading telescope one-tenth of a second of arc.

On August 25th and 26th, I tried the experiment of observing Mars on two wires, after the plan proposed by Dr. WINNECKE; but the inclination between the wires was so great that we at once abandoned this plan, not wishing to disturb the diaphragm of wires by inserting a new one at that time. In order to retain uniformity in the series we have not used the observations of Mars on those days. The observations of the stars made on the fixed wire have, however, been included in the determination of mean place, as also those made on other days, when the planet was not observed.

On Oct. 15, the reading telescope having been accidentally injured, the observation of Mars was made, using one microscope. This observation has also been omitted.

All the remaining observations, with the exception of Oct. 7, have been made in the manner before stated. On that day four microscopes were read for each limb of the planet, and the observation has been included in the series.

Explanation of the printed columns.

Column 1 contains the date.

Column 2 contains the name of the object and the declinometer scale reading for Mars. The numbers in parenthesis opposite "scale" specify the number of readings.

Column 3 contains the mean of the circle microscope readings for the centre of the object observed, corrected for runs and flexure.

Column 4 contains the refractions obtained as explained hereafter.

Column 5 contains the computed nadirs obtained by comparing the apparent declination of the star on the given date with the final declination found for the whole series. The daily adopted nadir used for the reduction of the observation of stars is given at the bottom of the page, and is assumed to have been constant for that day. During the year 1862, and prior to that time, we generally observed the nadir point in the morning, and adopted the Greenwich plan of combining our separate results, using the same nadir for a week, more or less, as the observations for nadir might indicate. This plan I have since been led to abandon. On examining the Mars series, it was found that on many days no nadir had been observed. This fact, together with the instability in our declinometer apparatus, of which I have before spoken, led me to think that the observations were not worth reducing for purposes of parallax. But my nadir investigations during the past year suggested the idea that these observations would throw some light on the stability or instability of the nadir point, independent of direct nadir observations. Our method of reduction was, first, to determine the mean declinations of all the stars with the nadir included; secondly, to apply the nadir for those days on which it was observed, and find the

mean declinations. The mean of these results gave us an approximate standard from which to determine the nadirs on all other days. By this mode of reduction—and under the circumstances I know of no better—the absolute declinations depend only on the observed nadirs.

In case the mean declinations of the stars should not be correct, the effect on Mars declination would be constant during the period when the same group of stars was observed. When this group was changed, there would be a sudden change in the planet's declination.

Our Mars observations may be divided into two groups; first, from August 18 to September 24; second, from September 25 to November 1.

The close agreement between our mean declinations of comparison stars and those used by WINNECKE, "*Beobachtungen des Mars*," would seem to indicate that they are very near the truth.

Although these observations show no very large or sudden changes in the nadir point, yet they clearly indicate that a nadir determined on one day will not answer for any other. We also conclude that the nadir point is liable to change during the time of observation.

The quantity in the parenthesis opposite Mars is a mean of all the numbers for the date. That in brackets [3.″54], September 4, is marked to show that the observation of δ Piscium was apparently bad. It was, however, used in finding the nadir for Mars. All the numbers in this column are to be increased one minute of arc.

Column 6 contains the reduction to mean place taken from Winnecke's '*Beobachtungen des Mars*,' corrected for (time + long. + 1.072 days.)

Column 7 contains the seconds of mean declination for the comparison stars for 1862.0.

Column 8 contains the apparent declination of the centre of Mars and the measured diameter Δ. The diameter is corrected for thickness of the wire, but not for irradiation.

The adopted nadirs, barometer and thermometer readings, with the respective hours of observation, will be found on a separate page.

Computations of refractions for September 4.

18h. 55m. Sid. T.		0h. 55m. Sid. T.	
Bar. 30.040, ...	= 0.03346	Bar. 30.075, ...	= 0.03396
Ex. Ther. 68°.0, ..	= 0.02553	Ex. Ther. 59°.7, ..	= 0.03271
Log. Corr., ..	= 0.05899	Log. Corr., ..	= 0.06667

Variation of Log. for 1h., ...	= +0.00128
Log. for 0h. Sid. T., ...	= 0.06549

Refraction of δ Piscium.

Log. for 0h. Sid. T., ...	= 0.06549
A. R. cor. 41 m., ...	= +0.00087
Log. 0h. 41m., ...	= 0.06636
Z. D. = + 35° 49′, log., ...	= 1.54962
Refraction = 41″.30, ...	= 1.61598

The refractions have been computed by the Greenwich tables, which are found in the Appendix of the Observations for 1836, as also expanded for great zenith distances in the volume of Observations for 1853. No attached thermometer reading is used with the barometer in these observations, since for all zenith distances less than 45°, the neglecting of it will never amount to 0″.01.

The barometer and thermometer are supposed to vary uniformly for the interval of time between the two readings; and the refractions are computed in proportion to the time.

Computation of δ Piscium.

Mean Circle Readings, corrected, ...	=	+35°	49′	49″.76
Nadir, ...	=	−	1	6 .30
		+35	48	43 .46
Refraction, ...		+		41 .30
		+35	49	24 .76
Latitude, ...		+42	39	49 .55
App. Dec., ...		+ 6	50	24 .79
Reduction, ...		−		26 .71
Mean Declination, 1862.0, ...	=	+ 6	49	58 .08

On the sheet of final mean declinations of comparison stars, the declination of δ Piscium is found to be +6° 49′ 58″.52, the difference being 0″.44. This applied to the nadir used gives from the observation of this star the corrected nadir:

	1′ 6″.74
20 Ceti gives, ...	7 .15
26 Ceti "	7 .42
80 Piscium "	[3 .54]
γ Piscium "	6 .91
3298 L. L. "	5 .84
ξ Piscium "	6 .50
	(1 6 .30)

The true nadir given by all the comparison stars, assuming the final declinations to be the standard. This is the quantity to be used for the reduction of Mars, assuming all the observations to have equal weight.

MEAN DECLINATION OF STARS

COMPARED WITH MARS (1862, 0.)

DATE.	261 L.L.	44 Pisc.	670 L.L.	15 Ceti.	60 Pisc.	δ Pisc.
	+0° 55′	+1° 10′	+4° 5′	−1° 15′	+5° 59′	+6° 49′
1862.	″	″	″	″	″	″
Aug. 18	...	...	...	...	...	59. 54
19	...	...	...	...	...	58. 45
20	...	...	...	...	...	58. 63
21	...	...	...	...	...	58. 23
24	...	...	...	...	...	59. 67
25	...	...	...	...	...	58. 22
26	...	...	...	...	...	...
29	...	...	...	...	...	58. 14
Sept. 2	...	...	...	...	...	58. 31
3	...	...	...	...	...	58. 47
4	...	...	...	...	...	58. 08
5	...	...	...	...	...	58. 21
7	...	...	...	...	...	57. 73
8	...	...	...	...	...	...
9	...	...	...	...	...	58. 27
10	...	...	...	...	...	59. 83
21	...	...	...	...	...	59. 92
22	...	...	...	...	...	58. 09
23	...	...	...	...	...	57. 72
24	...	...	...	...	...	57. 97
25	...	...	45. 02	48. 32	11. 86	...
26	...	...	45. 00	48. 66	11. 62	...
27	...	...	46. 06	46. 23	11. 61	...
Oct. 7	...	...	45. 15	47. 85	...	...
8	...	...	45. 18	48. 59	...	...
14	...	28. 88	46. 05	48. 57	...	...
15	...	27. 95	45. 70	48. 24	...	...
23	...	29. 60	44. 37	...	...	...
27	15. 81	29. 70	44. 12	...	...	...
28	15. 48	29. 36	45. 59	...	...	...
29	...	29. 54	44. 41	...	...	...
30	16. 04	29. 18	44. 48	...	...	...
Nov. 1	...	29. 74	45. 21	...	...	...
Mean, ...	15. 78	29. 24	45. 10	48. 06	11. 69	58. 52

MEAN DECLINATION OF STARS

COMPARED WITH MARS (1862, 0.)

DATE.		20 Ceti.	26 Ceti.	80 Pisc.	89 Pisc.	43 Ceti.
		−1° 53′	+0° 37′	+4° 55′	+2° 50′	−1° 10′
1862.		″	″	″	″	″
Aug.	18	- - -	32.99	05.47	- - -	- - -
	19	40.82	- - -	- - -	- - -	- -
	20	41.06	33.74	05.78	- - -	- - -
	21	40.52	33.40	- - -	- - -	- - -
	24	40.00	33.06	05.64	- -	- - -
	25	- - -	33.20	- - -	- - -	- - -
	26	40.29	- - -	05.41	- - -	- - -
	29	- - -	32.82	06.82	- - -	- - -
Sept.	2	40.23	33.62	05.80	- - -	- - -
	3	40.72	34.27	- - -	- - -	- - -
	4	41.79	32.51	08.72	- - -	- - -
	5	40.54	33.24	- - -	- - -	- - -
	7	42.04	34.73	06.14	- - -	- - -
	8	- - -	34.05	06.03	- - -	- - -
	9	40.21	34.02	04.59	- - -	- - -
	10	- - -	32.42	06.40	- - -	- - -
	21	40.49	33.84	06.93	- - -	- - -
	22	42.06	33.29	- - -	- - -	- - -
	23	41.53	33.40	- - -	- - -	- - -
	24	40.78	34.88	- - -	- - -	- - -
	25	41.65	- - -	- - -	- - -	22.14
	26	39.88	- - -	- - -	- - -	22.93
	27	41.67	- - -	- - -	- - -	23.14
Oct.	7	- - -	34.07	05.33	10.87	22.95
	8	- - -	- - -	05.77	10.96	22.32
	14	- - -	33.56	- - -	10.53	23.08
	15	- - -	34.51	04.59	11.46	- - -
	23	- - -	- - -	- - -	- - -	- - -
	27	- - -	33.13	- - -	- - -	- - -
	28	41.19	33.77	- - -	- - -	- - -
	29	- - -	- - -	- - -	- - -	- - -
	30	40.94	33.15	- - -	- - -	- - -
Nov.	1	41.29	35.24	- - -	- - -	- - -
Mean,......		40.94	33.63	05.96	10.95	22.76

*MEAN DECLINATION OF STARS

COMPARED WITH MARS (1862, 0.)

DATE.		2614 L.L.	μ Pisc.	γ Pisc.	3298 L.L.	ξ Pisc.
		−1° 07′	+5° 25′	+4° 47′	+2° 59′	+2° 30′
1862.		″	″	″	″	″
Aug.	18	- - -	- - -	- - -	- - -	- - -
	19	- - -	- - -	- - -	- - -	- - -
	20	- - -	- - -	- - -	- - -	- - -
	21	- - -	- - -	- - -	- - -	- - -
	24	- - -	49. 37	15. 53	41. 48	15. 20
	25	- - -	- - -	15. 41	- - -	16. 25
	26	- - -	50. 37	14. 81	40. 74	17. 05
	29	- - -	- - -	13. 20	42. 91	16. 38
Sept.	2	- - -	- - -	15. 00	41. 52	- - -
	3	- - -	- - -	15. 32	40. 82	15. 13
	4	- - -	- - -	14. 23	41. 66	16. 06
	5	- - -	- - -	14. 72	- - -	16. 48
	7	- - -	- - -	15. 10	40. 62	17. 20
	8	- - -	- - -	14. 30	41. 94	15. 37
	9	- - -	- - -	15. 09	41. 22	16. 32
	10	- - -	- - -	14. 85	40. 35	16. 33
	21	- - -	50. 25	13. 94	39. 67	15. 86
	22	- - -	- - -	15. 36	41. 54	17. 14
	23	- - -	49. 87	16. 19	- - -	17. 33
	24	- - -	50. 85	14. 38	41. 19	15. 76
	25	- - -	50. 35	- - -	- - -	- - -
	26	01. 75	51. 00	- - -	- - -	- - -
	27	03. 41	49. 46	- - -	- - -	- - -
Oct.	7	- - -	- - -	- - -	- - -	- - -
	8	- - -	- - -	- - -	- - -	- - -
	14	- - -	- - -	- - -	- - -	- - -
	15	- - -	- - -	- - -	- - -	- - -
	23	- - -	- - -	- - -	- - -	- - -
	27	- - -	- - -	- - -	- - -	- - -
	28	- - -	- - -	- - -	- - -	- - -
	29	- - -	- - -	- - -	- - -	- - -
	30	- - -	- - -	- - -	- - -	- - -
Nov.	1	- - -	- - -	- - -	- - -	- - -
Mean,......		02. 58	50. 19	14. 84	41. 20	16. 26

* This table contains the individual results and mean of the following observations:

MARS OBSERVATIONS.

Date.	Object.	Corrected Circle Readings.	Refractions.	Computed Nadir.	Reductions to 1862, 0.	Mean Declination, 1862, 0.	App. Obs'd Declination and Diam. Mars.	No. of measures each limb.	REMARKS.
		° ′ ″	″	″	″	″	° ′ ″		
1862. Aug. 21	δ Piscium, ...	35 49 50. 05	40. 80	4. 67	24. 85	58. 23			
	20 Ceti, ...	44 33 12. 02	55. 60	3. 96	26. 83	40. 52			
	26 Ceti, ...	42 2 3. 65	50. 92	4. 61	25. 96	33. 40			
	Mars 23′ 38″.19, .	39 46 24. 80	47. 04	(4. 41)	. .	. .	+2 53 42. 12 Δ 18. 87	4	
	Scale 24′ 0.″0, ..	39 46 46. 61	. .	. .	. .	. .			
24	δ Piscium, ...	35 49 48. 89	42, 04	5. 19	25. 29	59. 67			
	20 Ceti, ...	44 33 11. 44	57. 30	5. 40	27. 15	40. 00			
	26 Ceti, ...	42 2 4. 01	52. 50	6. 91	26. 32	33. 06			
	80 Piscium, ...	37 44 39. 98	45. 11	6. 66	25. 16	5. 64			
	Scale (3) 22′ 0″.0,	39 39 16. 55	. .	. .	. .	. .			
	Mars 22′ 8″.41, ..	39 39 24. 96	48. 34	(6. 30)	. .	. .	+3 0 42. 55 Δ 21. 57	4	Blazing: definition not good.
	μ Piscium, ...	37 13 57. 95	44. 32	7. 16	24. 25	49. 37			
	ν Piscium, ...	37 52 31. 03	45. 39	5. 65	23. 94	15. 53			
	3298 Lalande, ..	39 40 1. 88	48. 39	6. 06	24. 14	41. 48			
	ξ Piscium, ...	40 9 27. 37	49. 26	7. 40	24. 06	15. 20			

	29	δ Piscium,......	35 49 49.88	42.09	6.90	25.96	58.14			
		26 Ceti,........	42 2 3.81	52.59	7.33	26.85	32.82			
		80 Piscium, ...	37 44 38.26	45.20	5.66	25.79	6.82			
		Mars 23′ 53″.12,.	39 32 48.36	48.26	(6.54)	. .	. .	+ 3 7 19.47 Δ 22.96	4	Blazing badly.
		Scale (2) 24′ 0″.0,	39 32 55.24	. .	. .	. .	. .			
		ν Piscium	37 52 32.81	45.52	8.16	24.54	13.20			
		3298 Lalande, ..	39 39 59.91	48.54	4.81	24.71	42.91			
		ξ Piscium,......	40 9 25.65	49.43	6.40	24.61	16.38			
Sept.	2	δ Piscium,......	35 49 48.44	42.57	6.44	26.46	58.31			
		20 Ceti,........	44 33 10.06	58.01	5.52	27.94	40.23			
		26 Ceti,........	42 2 1.79	53.14	6.24	27.23	33.62			
		80 Piscium, ...	37 44 38.08	45.66	6.39	26.24	5.80			
		Scale 18′ 0″.0,...	39 31 40.36	. .	. .	. .	. .			
		Mars 18′ 16″.65,.	39 31 56.75	48.71	(6.09)	. .	. .	+3 8 10.18 Δ 21.55	5	Definition good. Aperture of object-glass reduced to 3 in
		Scale 18′ 0″.0,...	39 31 39.85	. .	. .	. .	. .			
		ν Piscium,......	37 52 29.90	45.91	6.07	24.97	15.00			
		3298 Lalande, ..	39 40 0.23	48.93	5.91	25.10	41.52			
	3	δ Piscium,......	35 49 48.06	42.23	5.85	26.59	58.47			
		20 Ceti,........	44 33 40.49	57.55	5.58	28.03	40.72			
		26 Ceti,........	42 2 1.04	52.72	5.16	27.32	34.27			
		Mars 22′ 8″.69,..	39 32 20.29	48.30	(5.84)	. .	. .	+3 7 46.80 Δ 21.87	4	
		Scale (2) 22′ 0″.0,	39 32 11.60	. .	. .	. .	. .			

MARS OBSERVATIONS—(CONTINUED).

DATE.	OBJECT.	Corrected Circle Readings.	Refractions.	Computed Nadir.	Reductions to 1862, 0.	Mean Declination, 1862, 0.	App. Obs'd Declination and Diam. Mars.	No. of measures each limb.	REMARKS.
1862.		° ′ ″	″	″	″	″	° ′ ″		
Sept. 3	ν Piscium,......	37 52 29. 41	45. 54	5. 32	25. 08	15. 32			
	3298 Lalande, ..	39 40 0. 79	48. 54	6. 18	25. 20	40. 82			
	ξ Piscium,......	40 9 25. 72	49. 41	6. 93	25. 09	15. 13			
Sept. 4	δ Piscium,......	35 49 49. 76	41. 30	6. 74	26. 71	58. 08			
	20 Ceti,........	44 33 13. 24	56. 29	7. 15	28. 11	41. 79			
	26 Ceti,........	42 2 4. 34	51. 58	7. 42	27. 42	32. 51			
	80 Piscium, ...	37 44 36. 33	44. 33	[3. 54]	26. 47	8. 72			
	Mars 12′ 49″.50 .	39 32 59. 15	47. 31	(6. 30)	. .	. .	+3 7 9. 39 Δ 23. 25	3	Blazing badly.
	Scale (2) 12′ 35″.0	39 32 44. 65	. .	. .	. .	. .			
	ν Piscium,......	37 52 31. 82	44. 61	6. 91	25. 19	14. 23			
	3298 Lalande, ..	39 40 1. 33	47. 56	5. 84	25. 30	41, 66			
	ξ Piscium,......	40 9 26. 18	48. 42	6. 50	25. 19	16. 06			
5	δ Piscium,......	35 49 50. 11	40. 77	6. 69	26. 84	58. 21			
	20 Ceti,........	44 33 12. 72	55. 56	5. 98	28. 19	40. 54			
	26 Ceti,........	42 2 4. 29	50. 89	6. 77	27. 51	33. 24			
	Mars 20′ 26″.37 :	39 33 51. 13	46. 68	(6. 42)	. .	. .	+3 6 18 .16 Δ 21 52	4	

	Scale (2) 20′ 0″.0	39 33 24.76	. .	. .	. .	. .			
	ν Piscium, ...	37 52 31.92	43.99	6.50	25.30	14.72			
	ξ Piscium, ...	40 9 26.46	47.70	6.16	25.29	16.48			
7	δ Piscium, ...	35 49 49.81	40.33	6.17	27.06	57.73			
	20 Ceti, ...	44 33 13.69	54.97	6.48	28.31	42.04			
	26 Ceti, ...	42 2 2.17	50.36	4.28	27.67	34.73			
	80 Piscium, ...	37 44 38.74	43.28	5.20	26.77	6.14			
	Scale 16′ 0″.0 ...	39 35 40.14	. .	. .	. .	. .			
	Mars 16′ 34″.03 .	39 36 14.06	46.26	(5.38)	. .	. .	+3 3 54.61 Δ 22.05	6	
	Scale (2) 16′ 0″.0	39 35 39.93	. .	. .	. .	. .			
	ν Piscium, ...	37 52 30.80	43.54	5.12	25.49	15.10			
	3298 Lalande, ..	39 40 2.33	46.41	5.96	25.57	40.62			
	ξ Piscium, ...	40 9 25.04	47.25	4.44	25.44	17.20			
8	26 Ceti, ...	42 2 1.80	50.88	4.50	27.74	34.05			
	80 Piscium, ...	37 44 37.81	43.77	4.85	26.86	6.03			
	Mars 18′ 12″.73 .	39 37 45.46	46.88	(4.96)	. .	. .	+3 2 22.17 Δ 21.85	4	Blazing.
	Scale (2) 18′ 0″.0	39 37 32.73	. .	. .	. .	. .			
	ν Piscium, ...	37 52 30.50	44.10	5.46	25.57	14.30			
	3298 Lalande, ..	39 39 59.86	47.03	4.18	25.64	41.94			
	ξ Piscium, ...	40 9 25.72	47.87	5.81	25.51	15.37			
Sept. 9	δ Piscium, ...	35 49 48.34	41.64	6.21	27.26	58.27			
	20 Ceti, ...	44 33 10.56	56.75	5.23	28.41	40.21			

MARS OBSERVATIONS — (CONTINUED).

DATE.	OBJECT.	Corrected Circle Readings.	Refractions.	Computed Nadir	Reductions to 1862, 0.	Mean Declination, 1862, 0.	App. Obs'd Declination and Diam. Mars.	No. of measures each limb.	REMARKS.
		° ′ ″	″	″	″	″	° ′ ″		
1862. Sept. 9	26 Ceti,........	42 2 1.69	52.00	5.57	27.80	34.02			
	80 Piscium, ...	37 44 39.20	44.69	7.33	26.95	4.59			
	Mars 16′ 32″.87 .	39 39 29.23	47.89	(5.98)	. .	. .	+ 3 0 38.41	4	
							Δ 21.00		
	Scale (2) 16′ 0″.0	39 38 56.36	. .	. .	. .	. .			
	ν Piscium, ...	37 52 29.79	44.97	5.71	25.66	15.09			
	3298 Lalande, ..	39 40 0.63	47.94	5.94	25.72	41.22			
	ξ Piscium,......	40 9 24.79	48.81	5.90	25.59	16.32			
10	δ Piscium,......	35 49 46.63	41.26	4.22	27.36	59.83			
	26 Ceti,........	42 2 3.26	51.53	6.74	27.87	32.42			
	80 Piscium, ...	37 44 37.36	44.28	5.09	27.04	6.40			
	Mars 24′ 39″.48 .	39 41 29.85	47.47	(5.57)	. .	. .	+2 58 37.80	3	
							Δ 23.42		
	Scale 24′ 40″.0 ..	39 41 30.37	. .	. .	. .	. .			
	ν Piscium,......	37 52 29.94	44.55	5.52	25.74	14.85			
	3298 Lalande, ..	39 40 1.45	47.49	6.38	25.79	40.35			
	ξ Piscium,......	40 9 24.76	48.33	5.46	25.66	16.33			

21	δ Piscium, ...	35 49 44. 81	42. 21	4. 35	28. 36	59. 92			
	20 Ceti, ...	44 33 09. 37	57. 53	5. 30	28. 89	40. 49			
	26 Ceti, ...	42 2 0. 29	52. 72	5. 54	28. 45	33. 84			
	80 Piscium, ...	37 44 35. 16	45. 31	4. 78	27. 90	6. 93			
	Mars 12′ 36″.17 .	40 15 5. 89	49. 58	(5. 71)	. .	. .	+2 24 59. 79 Δ 23. 55	4	Blazing badly.
	Scale (2) 12′ 35″.0	40 15 4. 72	. .	. .	. .	. .			
	μ Piscium, ...	37 13 53. 56	44. 52	5. 69	26. 97	50. 25			
	ν Piscium, ...	37 52 29. 23	45. 58	6. 65	26. 55	13. 94			
	3298 Lalande, ..	39 40 0. 53	48. 62	7. 28	26. 48	39. 67			
	ξ Piscium, ...	40 9 23. 63	49. 50	6. 15	26. 31	15. 86			
22	δ Piscium, ...	35 49 48. 79	41. 66	7. 85	28. 43	58. 09			
	20 Ceti, ...	44 33 13. 35	56. 76	8. 54	28. 92	42. 06			
	26 Ceti, ...	42 2 3. 21	51. 98	7. 76	28. 49	33. 29			
	Mars 16′ 22″.28 .	40 19 1. 67	48. 93	(7. 44)	. .	. .	+ 2 21 6. 39 Δ 23. 75	5	
	Scale (2) 16′ 00″.0	40 18 39. 39	. .	. .	. .	. .			
	ν Piscium, ...	37 52 30. 14	44. 86	6. 90	26. 61	15. 36			
	3298 Lalande, ..	39 40 1. 10	47. 81	7. 08	26. 52	41. 54			
	ξ Piscium, ...	40 9 24. 81	48. 66	6. 54	26. 36	17. 14			
23	δ Piscium, ...	35 49 50. 17	40. 95	8. 60	28. 51	57. 72			
	20 Ceti, ...	44 33 14. 12	55. 81	8. 39	28. 95	41. 53			
	26 Ceti, ...	42 2 4. 29	51. 13	8. 03	28. 53	33. 40			
	Mars 22′ 19″.38 .	40 23 1. 26	48. 27	(7. 72)	. .	. .	+ 2 17 7. 74 Δ 23. 58	4	

MARS OBSERVATIONS—(CONTINUED).

DATE.	OBJECT.	Corrected Circle Readings.	Refractions.	Computed Nadir.	Reductions to 1862, 0.	Mean Declination, 1862, 0.	App. Obs'd Declination and Diam. Mars.	No. of Measures each limb.	REMARKS.
		° ′ ″	″	″	″	″	° ′ ″		
1862.									
Sept. 23	Scale (2) 22′ 00″.0	40 22 41.88	. .	. .	. .	. .			
	μ Piscium,.......	37 13 57.21	43.16	8.12	27.11	49.87			
	ν Piscium,.......	37 52 30.29	44.20	6.45	26.67	16.19			
	ξ Piscium,.......	40 9 25.64	47.97	6.73	26.41	17.33			
24	δ Piscium,.......	35 49 48.12	42.31	7.99	28.59	57.97			
	20 Ceti,.........	44 33 11.14	57.66	7.28	28.97	40.78			
	26 Ceti,.........	42 2 0.69	52.85	6.19	28.57	34.88			
	Mars 26′ 31″.40 .	40 27 1.27	50.01	(7.36)	. .	. .	+2 13 5.63	4	
							Δ 22.95		
	Scale (2) 26′ 34″.0	40 27 3.87	. .	. .	. .	. .			
	μ Piscium,.......	37 13 54.33	44.64	6.78	27.17	50.85			
	ν Piscium,.......	37 52 30.15	45.73	7.90	26.73	14.38			
	3298 Lalande, ..	39 40 0.42	48.76	7.45	26.62	41.19			
	ξ Piscium,.......	40 9 25.14	49.64	7.94	26.45	15.76			
25	670 Lalande, ...	38 33 57.31	46.53	8.64	29.25	45.02			
	15 Ceti,.........	43 55 20.95	56.22	8.82	29.26	48.32			
	60 Piscium, ...	36 40 33.99	43.49	8.39	28.77	11.86			

	20 Ceti,........	44 33 13.32	57.44	9.27	29.00	41.65			
	Mars 31′ 34″.54 .	40 31 6.14	49.91	(8.58)	. .	. .	+2 9 2.08 △ 22.22	3	
	Scale (2) 31′ 0″.0	40 30 31.60	. .	. .	. .	. .			
	43 Ceti,........	43 49 56.04	56.03	7.94	28.18	22.14			
	μ Piscium,......	37 13 56.15	44.37	8.40	27.24	50.35			
26	670 Lalande, ...	38 33 56.92	46.36	8.15	29.32	45.00			
	15 Ceti,........	43 58 20.96	56.01	8.65	29.29	48.66			
	60 Piscium, ...	36 40 33.81	43.33	8.12	28.84	11.62			
	20 Ceti,........	44 33 11.21	57.25	6.99	29.02	39.88			
	Scale (2) 14′ 0″.0	40 34 45.37	. .	. .	. .	. .			
	Mars 14′ 27″.42 .	40 35 12.79	49.88	(7.89)	. .	. .	+2 4 54.77 △ 23.68	6	
	43 Ceti,........	43 49 56.44	55.88	8.22	28.21	22.93			
	μ Piscium,......	37 13 55.04	44.26	7.24	27.30	51.00			
27	670 Lalande, ...	38 33 56.26	45.73	6.89	29.35	46.06			
	15 Ceti,........	43 55 19.10	55.24	6.02	29.29	46.23			
	60 Piscium, ...	36 40 34.17	42.74	7.93	28.88	11.61			
	20 Ceti,........	44 33 13.60	56.45	8.58	29.02	41.67			
	Mars 17′ 31″.06 .	40 39 21.45	49.24	(7.70)	. .	. .	+2 0 46. 56 △ 22.71	4	Blazing. Atmosphere hazy.
	Scale (2) 17′ 0″.0	40 38 50.39	. .	. .	. .	. .			
	43 Ceti,........	43 49 57.26	55.07	8.23	28.21	23.14			
	μ Piscium, ...	37 13 57.00	43.61	8.58	27.33	49.46			
7	670 Lalande, ...	38 33 57.75	44.54	7.57	29.73	45.15			

MARS OBSERVATIONS—(CONTINUED).

DATE.	OBJECT.	Corrected Circle Readings.	Refractions.	Computed Nadir.	Reductions to 1862, 0.	Mean Declination, 1862, 0.	App. Obs'd Declination and Diam. Mars.	No. of Measures each limb.	REMARKS.
1862.		° ′ ″	″	″	″	″	° ′ ″		
Oct. 7	15 Ceti,	43 55 21.88	53.82	7.41	29.32	47.85			
	Mars,	41 18 17.34	49.16	(7.65)	. .	. .	+1 21 50.70		Read by microscopes—4 mic. for each limb.
							Δ 23.79		
	26 Ceti,	42 2 3.89	50.42	7.18	28.79	34.07			
	80 Piscium,	37 44 39.87	43.33	8.25	28.64	5.33			
	89 Piscium,	39 46 31.38	46.61	7.70	28.31	10.87			
	43 Ceti,	43 49 58.17	53.74	7.81	28.21	22.95			
8	670 Lalande,	38 33 57.10	44.00	6.40	29.75	45.18			
	15 Ceti,	43 55 22.18	53.13	7.01	29.31	48.59			
	Mars, 11′ 48″.51	41 21 37.46	48.63	(6.52)	. .	. .	+1 18 29.98	5	
							Δ 24.78		
	Scale 12′ 0″.0	41 21 48.25	. .	. .	. .	. .			
	80 Piscium,	37 44 38.82	42.78	6.67	28.66	5.77			
	89 Piscium,	39 46 30.73	46.02	6.47	28.32	10.96			
	43 Ceti,	43 49 57.11	53.05	6.04	28.19	22.32			
14	44 Piscium,	41 29 6.83	51.26	7.43	29.65	28.88			
	670 Lalande,	38 33 54.48	46.23	6.12	29.86	46.05			

	15 Ceti,........	43 55 20.16	55.81	7.58	29.22	48.57			
	Mars 21′ 5″.87 ..	41 37 59.01	51.54	(7.19)	. .	. .	+1 2 6.19	4	
							△ 24.95		
	Scale (2) 21′ 0″.0	41 37 53.14	. .	. .	. .	. .			
	26 Ceti,........	42 2 2.06	52.25	7.14	28.75	33.56			
	89 Piscium, ...	39 46 29.47	48.27	4.49	28.35	10.53			
	43 Ceti,........	43 49 55.97	55.65	7.39	28.08	23.08			
23	44 Piscium, ...	41 29 7.06	53.71	9.99	29.53	29.60			
	670 Lalande, ...	38 33 57.19	48.46	11.08	29.88	44.37			
	Mars 31′ 55″.89 .	41 47 19.94	54.36	(10.53)	. .	. .	+0 52 45.78	6	Bisected the centre by the eye.
	Scale (3) 32′ 0″.0	41 47 24.05	. .	. .	. .	. .			
27	44 Piscium, ...	41 29 7.80	52.59	9.52	29.44	29.70			
	261 Lalande, ...	41 44 21.17	53.03	9.95	29.52	15.81			
	670 Lalande, ...	38 33 58.12	47.44	10.96	29.85	44.12			
	Mars 21′ 6″.17 ..	41 44 29.60	53.12	(10.23)	. .	. .	+0 55 37.06	4	
							△ 20.84		
	Scale (3) 21′ 0″.0	41 44 23.43	. .	. .	. .	. .			
	26 Ceti,........	42 2 4.26	53.71	10.48	28.43	33.13			
28	261 Lalande, ...	41 44 21.14	53.14	10.00	29.49	15.48			
	44 Piscium, ...	41 29 7.81	52.67	9.58	29.41	29.36			
	670 Lalande, ...	38 33 56.32	47.57	9.21	29.83	45.59	+0 57 3.63		
	Mars 16′ 14″.06 .	41 43 2.46	53.12	(9.66)	. .	. .	△ 21.13	4	Very steady; thin clouds.
	Scale (2) 16′ 0″.0,	41 42 48.40	. .	. .	. .	. .			
	20 Ceti,........	44 33 13.45	58.66	9.95	28.33	41.19			

MARS OBSERVATIONS—(CONTINUED).

DATE.	OBJECT.	Corrected Circle Readings.	Refractions.	Computed Nadir.	Reductions to [illegible]	Mean Declin. [illegible]	App. Obs'd Declination and Diam. Mars.	No. of Comparisons [illegible]	REMARKS.
		° ′ ″	″	″	″	″	° ′ ″		
1862. Oct. 28	26 Ceti, ...	42 2 3. 36	53. 73	9. 56	28. 30	33. 77			
30	261 Lalande, . . .	41 44 21. 35	52. 00	9. 00	29. 42	16. 04			
	44 Piscium, ...	41 29 8. 74	51. 55	9. 32	29. 34	29. 18			
	670 Lalande, . . .	38 33 58. 05	46. 49	9. 88	29. 70	44. 48			
	Mars 13′ 40″.38 .	41 39 20. 56	51. 85	(9. 44)	. .	. .	+ 1 0 46. 58 ∆ 20. 25	4	
	Scale (2) 13′ 40″.0	41 39 20. 18	. .	. .	. .	. .			
	20 Ceti, ...	44 33 14. 15	57. 38	9. 26	28. 22	40. 94			
	26 Ceti, ...	42 2 4. 81	52. 55	9. 74	28. 30	33. 15			
Nov. 1	44 Piscium, ...	41 29 10. 16	50. 87	10. 00	29. 28	29. 74			
	670 Lalande, . . .	38 33 59. 19	45. 89	10. 39	29. 76	45. 21			
	Mars 25′ 57″.86 .	41 34 32. 21	51. 06	(10. 03)	. .	. .	+ 1 5 36. 49 ∆ 19. 47	4	Observed through thick clouds.
	Gilliss. (9), ...	41 33 56. 42	51. 06	. .	28. 99	43. 11			
	Scale (2) 26′ 0″.0	41 34 34. 35	. .	. .	. .	. .			
	20 Ceti, ...	44 33 16. 55	56. 67	10. 85	28. 12	41. 29			
	26 Ceti, ...	42 2 4. 68	51. 91	8. 89	28. 22	35. 24			

DATE.		Time.	Bar.	Ther.	Adopted Nadir.
1862.		H. M.	in.	°	′ ″
October	14..	0 28	29.880	50.1	1 7.07
		1 20	29.880	50.1	
	23..	0 15	30.203	32.8	1 10.35
		1 00	30.203	31.6	
	27..	22 20	29.607	36.0	1 9.98
		0 20	29.742	35.4	
	28..	22 27	30.040	40.0	1 9.70
		0 40	30.020	39.0	
	30..	22 35	29.922	48.0	1 9.26
		0 30	29.895	47.8	
November	1..	23 50	29.837	53.5	1 10.50
		1 00	29.835	52.5	

The flexure correction used is + 1″.34, for Dec. + 0°.

The runs of the microscopes have been assumed as constant during the whole period of observation. The following observed values will show that in considering the runs constant we do not introduce a greater error than would result from using a single determination:

RUNS FOR 100″.

	Sept. 23d, Temp. 60°.	Oct. 7th, Temp. 66°.	Oct. 30th, Temp. 50°.	Oct. 31st, Temp. 50°.
	″	″	″	″
Mic. E,....	+ 0.80	+ 1.00	+ 0.52	+ 0.66
F,....	— 0.58	— 0.20	— 0.20	— 0.20
G,....	+ 1.87	+ 1.87	+ 1.83	+ 1.80
H,....	+ 0.30	+ 0.41	+ 0.58	+ 0.52
Mean, ...	+ 0.60	+ 0.77	+ 0.68	+ 0.69

The runs computed separately for each microscope are as follows: 100″, Mic. E, + 0″.80; F, — 0″.28; G, + 1″.80; H, + 0″.38; Mean, + 0″.68.

In a few cases the barometer and thermometer were read only once, and near the middle of the observations for the night. In such cases, the observations made at 8 P. M., M. T., have also been used to determine the changes. It is not possible for an error of more than 0".05 to arise from this cause.

F.

OBSERVATIONS OF THE PLANET NEPTUNE, MADE WITH THE OLCOTT MERIDIAN CIRCLE, 1861.

DATE.		M. T. Dudley Observatory.	App. A. R.	App. Decl.
1861.		h m s	h m s	° ′ ″
Sept.	24	11 46 54.61	. . . .	—1 13 44.76
	25	11 42 52.65	0 2 45.70	1 14 25.34
	28	11 30 46.79	0 2 27.51	1 16 25.03
Oct.	3	11 10 37.29	0 1 57.46	1 19 41.17
	8	10 50 28.42	0 1 28.05	1 22 51.17
	9	10 46 26.66	0 1 22.18	. . . .
	14	10 26 18.78	0 0 53.76	1 26 29.20
	28	9 30 4.42	23 59 41.92	1 33 59.68
	29	9 26 3.94	23 59 37.34	1 34 27.89
Nov.	18	8 6 12.93	23 58 24.31	1 41 45.60
	19	8 2 14.52	23 58 21.81	1 42 00.50
	22	7 50 19.74	23 58 14.74	1 42 38.27
	25	7 38 25.94	23 58 8.67	1 43 10.80
	26	7 34 28.37	23 58 7.00	1 43 20.93
	30	7 18 38.92	23 58 1.18	1 43 46.47
Dec.	2	7 10 44.88	23 57 58.96	1 43 56.49
	3	7 6 48.04	23 57 58.02	1 43 58.16
	14	6 23 31.28	23 57 56.39	1 43 42.84
	17	6 11 45.83	23 57 58.59	1 43 20.11
	18	6 7 50.91	23 57 59.59	1 43 11.63
	21	5 56 6.92	23 58 3.34	1 42 37.10
	24	5 44 24.05	23 58 8.21	1 41 59.02
	30	5 21 1.61	23 58 21.28	—1 40 17.91

OBSERVATIONS OF THE PLANET NEPTUNE.

Date.	American Ephemeris.		Date.	American Ephemeris.	
	[illegible]	[illegible]		Corr. A. R.	Corr. N. P. D.
1861.	s	"	1861.	s	"
Sept. 24	—	+10.41	Nov. 25	1.59	10.44
27	−1.65	11.09	26	1.50	11.57
28	1.66	11.66	30	1.48	9.11
Oct. 5	1.58	12.22	Dec. 2	1.51	10.00
8	1.59	11.07	3	1.54	8.36
9	1.57	—	14	1.49	11.14
14	1.65	11.40	17	1.50	10.93
28	1.56	9.94	18	1.49	11.53
29	1.53	9.64	21	1.48	9.30
Nov. 18	1.53	10.40	24	1.47	10.80
19	1.47	10.86	30	−1.51	+10.83
22	1.52	9.73			

MEAN CORRECTION TO AMERICAN EPHEMERIS.

	A. R.	N. P. D.
	s	"
September and October, ...	− 1.57	+ 11.04
November, ...	− 1.52	+ 10.17
December, ...	− 1.50	+ 10.36
MEAN DAY.		
November 17th, ...	− 1.529	+ 10.52

Variation of A. R. for 100 days, = 0.^{s}109. Mean error of one observation, A. R., = ± 0.^{s}029. Decl. = ± 0″.80.

The transits on October 28th, November 19th, and December 2d, were observed on 9, 10 and 7 wires, respectively. In all the other observations 13 wires were used, and the times of transit recorded on the chronograph. Any change in the rate of the clock (during the time of observation) was satisfactorily determined by comparison with two other clocks, by

causing their pendulums to make records on the chronograph at intervals of 30 minutes.

In converting the chronographic records into time, every wire was measured to the hundredth of a second. And in the "mean," and all subsequent reductions, the thousandths were retained; being rejected in the final results only.

OBSERVATIONS OF THE PLANET NEPTUNE, 1862.

DATE.		M. T. Dudley Observatory.	App. A. R.	App. Decl.
1862.		h m s	h m s	° ′ ″
Aug.	21	14 13 12.8	0 14 33.93	+ 0 0 13.26
	24	14 1 10.7	. . . . .	− 0 2 27.18
	26	13 53 8.8	0 14 9.39	2 34.57
	29	13 41 5.7	13 54.00	4 21.97
Sept.	2	13 25 0.7	13 32.54	6 48.04
	3	13 20 59.4	13 27.11	7 27.39
	4	13 16 58.0	. . . .	8 04.73
	5	13 12 56.5	. . . .	8 41.63
	7	13 4 53.4	13 4.72	9 58.21
	9	12 56 50.0	12 53.13	11 15.60
	10	12 52 48.4	12 47.37	11 52.38
	21	12 8 27.9	11 41.64	19 10.56
	22	12 4 26.0	11 35.65	19 53.24
	23	12 0 23.8	. . . .	20 32.45
	24	11 56 22.1	. . . .	21 13.68
	25	11 52 20.0	11 17.38	21 52.74
	26	11 48 18.1	11 11.37	22 32.47
	27	11 44 16.1	11 5.23	23 13.75
Oct.	7	11 3 56.9	10 4.89	29 45.55
	8	10 59 55.1	9 59.01	30 22.96
	14	10 35 45.0	9 24.23	. . . .
	15	10 31 43.2	9 18.40	34 42.58
	20	10 11 36.6	. . .	37 35.79
	23	9 59 32.8	8 35.15	39 16.67
	27	9 43 29.1	8 14.95	41 22.86
	28	9 39 28.3	8 10.03	41 53.33
	29	9 35 27.5	8 5.14	42 24.26
	30	9 31 26.9	8 0.45	42 54.11
	31	9 27 26.4	7 55.90	43 21.66
Nov.	1	9 23 25.9	7 51.24	43 47.74
	14	8 31 27.9	6 59.89	48 56.94

MARS OBSERVATIONS — (CONTINUED).

DATE.	OBJECT.	Corrected Circle Readings.	Refractions.	Computed Nadir.	Reductions to 1862, 0.	Mean Declination, 1862, 0.	App. Obs'd Declination and Diam. Mars.	No. of Measures each limb.	REMARKS.
		° ′ ″	″	″	″	″	° ′ ″		
1862. Sept. 23	Scale (2) 22′ 00″.0	40 22 41.88	. .	. .	. .	. .			
	μ Piscium, ...	37 13 57.21	43.16	8.12	27.11	49.87			
	ν Piscium, ...	37 52 30.29	44.20	6.45	26.67	16.19			
	ξ Piscium, ...	40 9 25.64	47.97	6.73	26.41	17.33			
24	δ Piscium, ...	35 49 48.12	42.31	7.99	28.59	57.97			
	20 Ceti, ...	44 33 11.14	57.66	7.28	28.97	40.78			
	26 Ceti, ...	42 2 0.69	52.85	6.19	28.57	34.88			
	Mars 26′ 31″.40 .	40 27 1.27	50.01	(7.36)	. .	. .	+2 13 5.63 Δ 22.95	4	
	Scale (2) 26′ 34″.0	40 27 3.87	. .	. .	. .	. .			
	μ Piscium, ...	37 13 54.33	44.64	6.78	27.17	50.85			
	ν Piscium, ...	37 52 30.15	45.73	7.90	26.73	14.38			
	3298 Lalande, ..	39 40 0.42	48.76	7.45	26.62	41.19			
	ξ Piscium, ...	40 9 25.14	49.64	7.94	26.45	15.76			
25	670 Lalande, ...	38 33 57.31	46.53	8.64	29.25	45.02			
	15 Ceti, ...	43 55 20.95	56.22	8.82	29.26	48.32			
	60 Piscium, ...	36 40 33.99	43.49	8.39	28.77	11.86			

		20 Ceti,........	44 33 13. 32	57. 44	9. 27	29. 00	41. 65			
		Mars 31′ 34″.54 .	40 31 6. 14	49. 91	(8. 58)	. .	. .	+2 9 2. 08	3	
								Δ 22. 22		
		Scale (2) 31′ 0″.0	40 30 31. 60	. .	. .	. .	. .			
		43 Ceti,........	43 49 56. 04	56. 03	7. 94	28. 18	22. 14			
		μ Piscium,......	37 13 56. 15	44. 37	8. 40	27. 24	50. 35			
	26	670 Lalande, ...	38 33 56. 92	46. 36	8. 15	29. 32	45. 00			
		15 Ceti,........	43 58 20. 96	56. 01	8. 65	29. 29	48. 66			
		60 Piscium, ...	36 40 33. 81	43. 33	8. 12	28. 84	11. 62			
		20 Ceti,........	44 33 11. 21	57. 25	6. 99	29. 02	39. 88			
		Scale (2) 14′ 0″.0	40 34 45. 37	. .	. .	. .	. .			
		Mars 14′ 27″.42 .	40 35 12. 79	49. 88	(7. 89)	. .	. .	+2 4 54. 77	6	
								Δ 23. 68		
		43 Ceti,........	43 49 56. 44	55. 88	8. 22	28. 21	22. 93			
		μ Piscium,......	37 13 55. 04	44. 26	7. 24	27. 30	51. 00			
	27	670 Lalande, ...	38 33 56. 26	45. 73	6. 89	29. 35	46. 06			
		15 Ceti,........	43 55 19. 10	55. 24	6. 02	29. 29	46. 23			
		60 Piscium, ...	36 40 34. 17	42. 74	7. 93	28. 88	11. 61			
		20 Ceti,........	44 33 13. 60	56. 45	8. 58	29. 02	41. 67			
		Mars 17′ 31″.06 .	40 39 21. 45	49. 24	(7. 70)	. .	. .	+2 0 46. 56	4	Blazing. Atmosphere hazy.
								Δ 22. 71		
		Scale (2) 17′ 0″.0	40 38 50. 39	. .	. .	. .	. .			
		43 Ceti,........	43 49 57. 26	55. 07	8. 23	28. 21	23. 14			
		μ Piscium, ...	37 13 57. 00	43. 61	8. 58	27. 33	49. 46			
Oct.	7	670 Lalande, ...	38 33 57. 75	44. 54	7. 57	29. 73	45. 15			

OBSERVATIONS OF THE PLANET NEPTUNE.

Date.		M. T. Dudley Observatory.	App. A. R.	App. Decl.
1863.		h m s	h m s	° ′ ″
Oct.	19	10 25 3.5	+0 27 26.27	+0 15 23.76
	20	10 21 2.2	27 20.96	14 46.49
	21	10 17 4.6	27 15.41	14 14.47
	22	10 12 58.6	27 9.90	13 38.70
	29	9 44 51.6	26 33.62	9 51.36
Nov.	4	9 20 48.1	26 5.27	6 57.14
	19	8 20 52.4	25 8.02	+0 1 55.71
	25	7 58 2.3	24 49.26	- - -
	27	7 49 4.2	24 47.07	−0 0 28.10
	30	7 37 10.6	24 41.15	1 10.90
Dec.	4	7 21 20.5	24 34.70	1 42.13
	7	7 9 29.4	24 31.31	1 55.28
	8	7 5 32.5	24 30.33	1 58.46
	10	6 57 39.3	24 28.95	2 2.12
	23	6 6 35.4	24 31.94	−0 1 5.21
Jan.	2	5 27 33.0	0 24 48.74	+0 1 14.40
1864.				
Sept.	19	12 31 25.6	28 51.63	+1 26 35.53
	20	12 3 12.0	28 9.29	21 59.00
	27	11 59 10.1	28 3.25	21 19.90
	30	11 47 3.9	27 44.76	19 19.14
Oct.	4	11 30 56.1	27 20.49	16 42.34
	11	11 2 42.6	26 38.29	12 9.90
	22	10 18 24.6	25 35.00	5 30.59
	24	10 10 21.9	25 24.12	4 22.85
	25	10 6 20.6	25 18.71	3 49.63
Nov.	1	9 38 13.6	24 42.96	0 7.32
	2	9 34 12.9	24 38.16	+0 59 38.18
	14	8 46 10.7	23 46.79	54 29.07
	25	8 2 20.8	23 11.81	51 10.23
	30	7 42 30.0	23 0.47	50 9.07
Dec.	1	7 38 32.2	22 58.56	49 58.35
	8	7 10 50.6	22 48.35	49 14.18
	14	6 47 11.2	22 44.38	49 4.12
	20	6 23 36.3	0 22 44.94	+0 49 27.11

OBSERVATIONS OF THE PLANET NEPTUNE.

DATE.		American Ephemeris.	
	Δ α	Δ N. P. D.	Obs.
1863.	s	"	
September 7	—2.28	+14.6	H
9	2.31	. .	H
15	2.25	13.7	H
16	2.16	14.7	H
23	2.30	14.4	H
27	2.21	13.1	H
28	2.26	15.8	H
29	2.28	15.2	H
30	2.17	15.2	H
October 14	2.24	16.4	H
15	2.27	14.9	Mc
17	2.00	16.6	H
19	2.27	14.7	H
20	2.13	16.9	H
21	2.18	14.3	Mc
22	2.26	15.9	Mc
29	2.18	15.9	H
November 4	2.12	15.1	Mc
19	2.13	16.2	Mc
26	2.10	. .	S
27	2.08	14.4	Mc
30	2.00	15.0	Mc
December 4	2.12	14.9	H
7	2.03	14.8	H
8	2.09	15.9	H
10	2.07	14.8	Mc
23	2.01	14.6	H
January 2	2.06	13.8	H
1864.			
September 19	2.53	19.7	H
20	2.51	17.6	H
27	2.45	17.8	H
30	2.60	18.0	H
October 4	2.43	16.5	H
11	2.39	17.4	H
22	2.43	16.4	H
24	2.42	15.9	H
25	—2.47	+15.7	H

MARS OBSERVATIONS — (CONTINUED).

DATE.	OBJECT.	Corrected Circle Readings.	Refractions.	Computed Nadir.	Reductions to 1862, 0.	Mean Declination, 1862, 0.	App. Obs'd Declination and Diam. Mars.	No. of measures each limb.	REMARKS.
1862.		° ′ ″	″	″	″	″	° ′ ″		
Oct. 28	26 Ceti,........	42 2 3.36	53.73	9.56	28.39	33.77			
30	261 Lalande,...	41 44 21.35	52.00	9.00	29.42	16.04			
	44 Piscium,....	41 29 8.74	51.55	9.32	29.34	29.18			
	670 Lalande,...	38 33 58.05	46.49	9.88	29.79	44.48			
	Mars 13′ 40″.38 .	41 39 20.56	51.85	(9.44)	. .	. .	+ 1 0 46.58	4	
							Δ 20.25		
	Scale (2) 13′ 40″.0	41 39 20.18	. .	. .	. .	. .			
	20 Ceti,........	44 33 14.15	57.38	9.26	28.22	40.94			
	26 Ceti,........	42 2 4.81	52.55	9.74	28.30	33.15			
Nov. 1	44 Piscium,....	41 29 10.16	50.87	10.00	29.28	29.74			
	670 Lalande,...	38 33 59.19	45.89	10.39	29.76	45.21			
	Mars 25′ 57″.86 .	41 34 32.21	51.06	(10.03)	. .	. .	+ 1 5 36.49	4	Observed through thick clouds.
							Δ 19.47		
	Gilliss. (9),.....	41 33 56.42	51.06	. .	28.99	43.11			
	Scale (2) 26′ 0″.0	41 34 34.35	. .	. .	. .	. .			
	20 Ceti,........	44 33 16.55	56.67	10.85	28.12	41.29			
	26 Ceti,........	42 2 4.68	51.91	8.89	28.22	35.24			

	28	12 30 2.9	1 53.41	13 5 50.81	−7.26	−45.5	H	15	
Oct.	3	12 5 21.4	0 56 50.58	12 32 43.59	−7.29	−44.4	H	15	Faint.
	9	11 35 41.2	50 44.86	11 49 22.01	−7.18	−45.6	H	15	
				(52) EUROPA (B. J., 1863).					
Sept.	23	12 57 11.2	1 9 23.34	−2 51 52.96	−2.38	+18.6	H	4	
	25	12 48 0.9	8 4.65	3 4 1.13	−2.57	+16.4	H	15	
	28	12 34 11.3	6 2.47	3 22 11.16	−2.58	+18.5	H	15	
Oct.	3	12 10 59.9	2 30.01	3 51 38.76	−2.59	+17.1	H	15	
	9	11 43 2.8	0 58 7.60	. . . . . .	−2.67	. .	H	15	
	14	11 19 46.3	54 30.12	. . . . . .	−2.59	. .	H	15	
				(71) NIOBE.					
Oct.	14	7 59 29.4	21 33 40.28	+0 9 54.04	. .	. .	H	15	
	24	7 20 36.4	34 6.42	16 16.86	. .	. .	H	15	
	29	7 2 0.3	35 10.05	22 7.30	. .	. .	H	15	
1862.				**(11) PARTHENOPE (Astr. Nachrichten, 1368).**					
July	25	12 11 50.3	20 26 24.48	−18 59 19.83	−2.77	+18.4	H	15	
	30	11 47 38.9	21 51.90	19 29 7.85	−2.75	+17.6	H	15	
Aug.	4	11 23 34.1	17 25.93	19 57 57.00	−2.56	+16.4	H	15	
	6	11 14 0.3	15 43.66	20 9 5.16	−2.54	+18.9	H	15	
	8	11 4 29.7	14 4.63	20 19 49.91	−2.52	+16.2	H	15	
	9	10 59 45.8	13 16.50	20 25 6.33	−2.55	+16.6	H	15	
	16	10 27 1.3	8 12.45	20 59 13.71	. .	. .	H	15	
	18	10 17 2.8	6 57.45	21 7 58.70	. .	. .	H	15	
	19	10 13 24.1	6 22.53	21 12 14.73	. .	. .	H	15	

OBSERVATIONS OF ASTEROIDS.

(24) THEMIS—(*continued*).

DATE.	M. T. Dudley Obs.	App. A. R.	App. Dec.	Δ α	Δ N. P. D.	Obs.	No. of Wires.	Remarks.
1861.	h m s	h m s	° ′ ″	s	″			
Sept. 13	11 22 45.0	22 55 16.11	7 51 44.70	. .	. .	.	.	Dec. bad.
24	10 32 11.5	22 47 56.40	−8 34 20.71	. .	. .	.	.	
(25) PHOCAEA (Berlin Jahrbuch, 1863).								
Sept. 23	12 3 31.4	0 15 34.74	+23 18 41.98	+1.17	+8.8	H	15	
24	11 58 52.6	14 51.71	22 59 56.99	+0.96	+6.4	H	15	
25	11 54 14.1	14 8.98	22 40 53.30	+0.97	+3.2	H	15	
28	11 40 19.8	12 2.14	21 41 46.63	+0.98	+3.5	H	15	
Oct. 9	10 50 10.4	5 6.52	17 50 28.27	+1.01	+6.0	H	15	
(28) BELLONA (B. J., 1863).								
Oct. 3	12 14 4.5	1 5 35.08	−4 33 54.02	−0.44	+6.5	H	15	Faint.
(30) URANIA (B. J., 1863).								
June 26	11 56 13.3	18 17 22.00	−25 22 52.70	+8.54	−6.3	H	15	
29	11 41 9.2	. . . .	25 21 47.06	. .	−3.3	H	.	
(43) ARIADNE (B. J., 1863).								
Sept. 23	12 54 30.9	1 6 42.66	+13 34 58.09	−7.24	−44.5	H	15	
25	12 44 46.0	4 49.28	13 23 54.15	−7.22	−47.5	H	15	

	28	12 30 2.9	1 53.41	13 5 50.81	−7.26	−45.5	H	15	
Oct.	3	12 5 21.4	0 56 50.58	12 32 43.59	−7.29	−44.4	H	15	Faint.
	9	11 35 41.2	50 44.86	11 49 22.01	−7.18	−45.6	H	15	
			(52) EUROPA (B. J., 1863).						
Sept.	23	12 57 11.2	1 9 23.34	−2 51 52.96	−2.38	+18.6	H	4	
	25	12 48 0.9	8 4.65	3 4 1.13	−2.57	+16.4	H	15	
	28	12 34 11.3	6 2.47	3 22 11.16	−2.58	+18.5	H	15	
Oct.	3	12 10 59.9	2 30.01	3 51 38.76	−2.59	+17.1	H	15	
	9	11 43 2.8	0 58 7.60	. . . . . .	−2.67	. .	H	15	
	14	11 19 46.3	54 30.12	. . . . . .	−2.59	. .	H	15	
			(71) NIOBE.						
Oct.	14	7 59 29.4	21 33 40.28	+0 9 54.04	. .	. .	H	15	
	24	7 20 36.4	34 6.42	16 16.86	. .	. .	H	15	
	29	7 2 0.3	35 10.05	22 7.30	. .	. .	H	15	
1862.			(11) PARTHENOPE (Astr. Nachrichten, 1368).						
July	25	12 11 50.3	20 26 24.48	−18 59 19.83	−2.77	+18.4	H	15	
	30	11 47 38.9	21 51.90	19 29 7.85	−2.75	+17.6	H	15	
Aug.	4	11 23 34.1	17 25.93	19 57 57.00	−2.56	+16.4	H	15	
	6	11 14 0.3	15 43.66	20 9 5.16	−2.54	+18.9	H	15	
	8	11 4 29.7	14 4.63	20 19 49.91	−2.52	+16.2	H	15	
	9	10 59 45.8	13 16.50	20 25 6.33	−2.55	+16.6	H	15	
	16	10 27 1.3	8 12.45	20 59 13.71	. .	. .	H	15	
	18	10 17 2.8	6 57.45	21 7 58.70	. .	. .	H	15	
	19	10 13 24.1	6 22.53	21 12 14.73	. .	. .	H	15	

OBSERVATIONS OF ASTEROIDS.

(39) LAETITIA (B. J., 1864).

DATE.	M. T. Dudley Obs.	App. A. R.	App. Dec.	Δ α	Δ N. P. D.	Obs.	No. of Wires.	Remarks.
1862.	h m s	h m s	° ′ ″	s	″			
June 28	12 27 11.5	18 55 21.13	—9 2 28.24	—3.45	+15.4	H	15	
July 1	12 12 51.9	52 48.89	10 19.27	—3.10	+15.4	H	15	
3	12 3 17.2	51 5.69	16 11.80	—3.39	+14.5	H	7	
(48) DORIS (B. J., 1864).								
July 25	11 58 59.9	20 13 31.99	—11 22 33.15	+3.30	—3.3	H	15	
30	11 35 33.1	9 44.10	39 36.51	+3.55	—5.3	H	15	
(55) PANDORA (B. J., 1864).								
July 25	11 5 13.9	19 19 37.18	—33 37 34.20	—5.31	+12.1	H	9	
30	10 40 58.5	15 0.50	34 41.79	—5.07	+10.3	H	15	
1863. (1) CERES (Supplement N. A., 1866).								
Aug. 26	8 59 30.3	19 18 45.26	—31 44 38.14	+0.69	—0.8	Mc	15	
27	8 55 18.1	18 28.90	. 44 35.00	+0.68	+0.1	Mc	15	
Sept. 1	8 34 41.5	17 31.69	. . . .	+0.75	. .	H	4	
5	8 18 40.8	17 14.58	40 8.43	+0.52	+1.7	Mc	15	
10	7 59 16.1	17 29.48	34 58.88	+0.58	+3.5	Mc	15	

	14	7 44 12.9	18 9.95	29 35.26	+0.80	+2.3	Mc	5
	15	7 40 30.6	18 23.64	28 4.11	+0.58	+2.3	Mc	15
	16	7 36 50.1	18 39.06	26 31.22	+0.55	+2.1	Mc	15
	22	7 15 18.2	19 20 42.96	15 53.54	+0.78	−0.6	Mc	15
	24	7 8 18.8	21 35.48	12 0.45	+0.67	+4.3	Mc	15
	28	6 54 36.3	23 36.98	3 27.24	+0.65	+3.6	Mc	15
	29	6 51 13.9	24 10.57	1 9.86	+0.57	+1.9	Mc	15
	30	6 47 52.8	24 45.52	−30 58 52.35	+0.59	+3.1	Mc	15
Oct.	1	6 44 33.1	19 25 21.77	56 30.64	+0.64	+3.0	Mc	15
	13	6 6 8.2	34 9.18	24 25.05	+0.87	+3.4	Mc	15
(2) PALLAS (Supplement N. A., 1866).								
Aug.	24	7 49 7.4	18.00 17.67	. . . . . .	−0.34	. .	Mc	15 *
	27	7 37 28.1	00 25.10	+14 39 40.91	−0.20	+2.0	Mc	15
(5) ASTREA (Supplement N. A., 1866).								
March	9	10 44 2.3	9 53 20.01	+15 25 38.40	−3.43	−7.9	H	15
	16	10 13 14.6	50 3.19	16 1 47.47	−3.29	−5.9	H	15
	18	10 4 41.8	49 22.06	10 13.68	−3.14	−4.3	H	15
April	9	8 38 48.0	49 58.27	46 48.26	−2.69	−4.7	H	15
	13	8 24 44.4	51 38.65	42 57.54	−2.61	−4.8	H	15
	14	8 21 17.8	52 8.01	41 31.80	−2.48	−4.5	H	15
(9) METIS (B. J., 1865).								
June	13	10 46 1.2	16 13 48.53	−21 44 16.15	+0.28	+4.2	H	15
	15	10 36 17.6	11 56.41	43 15.13	+0.13	+2.5	H	15
	16	10 30	. . . .	42 46.64	. .	+2.9	H	. .

* Personal equation applied to clock error.

OBSERVATIONS OF ASTEROIDS.

DATE.	M. T. Dudley Obs.	App. A. R.	App. Dec.	Δ α	Δ N. P. D.	Obs.	No. of Wires.	Remarks.
		(15) EUNOMIA (B. J., 1865).						
1863.	h m s	h m s	° ′ ″	s	″			
April 27	10 48 11.5	13 10 41.02	—25 52 05.63	—0.29	+1.5	H	15	
May 1	10 29 17.6	7 30.25	26 06.52	—0.21	—2.3	H	15	
		(20) MASSALIA (B. J., 1865).						
Aug. 27	12 9 9.7	22 32 52.34	—8 11 59.43	+2.82	—16.7	H	15	
Sept. 1	11 44 53.5	28 14.91	40 6.78	+2.89	—14.4	H	15	
2	11 40 2.7	27 19.68	45 42.09	+3.14	—15.9	H	15	*
4	11 30 20.4	25 29.09	56 49.76	+2.97	—18.5	H	15	
5	11 25 29.9	24 34.37	9 2 26.93	+2.95	—13.2	Mc	15	
10	11 1 23.7	20 6.98	29 26.12	+2.77	—15.7	Mc	15	
16	10 32 52.4	15 10.25	59 32.36	+3.10	—15.5	H	15	
		(21) LUTETIA (Ast. Nach., 1405).						
Aug. 27	11 53 21.6	22 17 1.63	—16 51 43.65	—2.53	+12.9	H	15	
Sept. 1	11 29 31.9	12 50.84	17 15 32.04	—2.42	+15.1	H	15	
2	11 24 47.6	12 2.26	19 47.13	—2.34	+12.3	H	15	*
4	11 15 21.0	10 27.23	27 51.59	—2.26	+11.5	H	15	
5	11 10 38.9	9 40.93	31 38.75	—2.24	+11.7	Mc	15	
9	10 52 0.6	6 45.81	44 53.90	—2.39	+11.4	Mc	15	

				(51) NEMAUSA (B. J., 1865).						
Sept.	15	12 50 31.5	0 9 12.15	+0 7 43.08	—0.02	+ 4.0	H		15	
	16	12 25 47.1	8 23.59	—0 2 01.36	—0.09	+ 4.2	H		15	
	22	11 57 14.9	3 25.95	1 1 05.94	—0.11	+ 6.3	H		15	
	23	11 52 29.1	2 35.97	10 55.62	+0.03	+ 4.8	H		15	
	27	11 33 26.5	23 59 16.44	50 02.15	+0.07	+ 5.0	H		15	Very faint.
Sept.	28	11 28 41.3	58 27.00	59 41.48	+0.02	+ 5.1	H		15	Faint.
	29	11 23 56.4	57 37.87	2 9 16.24	—0.08	+ 4.8	H		15	Faint.
				(64) ANGELINA (Ast. Nach., 1438).						
Oct.	17	9 57 3.4	23 41 28.58	—0 15 38.59	—0.42	+ 1.6	H		15	
	19	9 48 2.2	40 18.94	23 21.75	—0.43	+ 1.5	H		15	
	29	9 4 11.9	35 47.05	54 31.11	—0.41	+ 3.4	H		15	
				(65) CYBELE (Ast. Nach., 1420).						
Sept.	7	12 9 15.4	23 16 20.14	. . . .	—4.06	. .	H		4	
	14	11 37 3.6	11 38.96	—6 2 52.10	—4.04	+23.9	H		15	
	16	11 27 53.0	10 19.93	12 49.95	—4.07	+24.4	H		15	
	22	11 0 29.3	6 31.08	41 27.98	—4.12	+20.6	H		15	
	28	10 33 24.6	3 1.20	7 7 47.88	—3.76	+24.2	H		15	
	30	10 24 28.0	1 56.24	15 50.04	—3.94	+20.6	Mc		15	Very faint.
				(79) EURYNOME.						
Sept.	23	12 45 27.0	0 55 42.57	+8 58 40.99	. .	. .	H		4	
	29	12 17 38.7	0 51 29.08	+8 13 19.95	. .	. .	H		15	
	30	12 12 58.3	0 50 44.39	+8 5 15.65	. .	. .	H		15	

* Personal equation applied to clock error.

(43) ARIADNE.

t. 19	9 17 58.5	21 14 52.75	—9 43 14.40	. .	. .	H	1	Zone Obs.
20	9 14 0.1	14 50.30	9 45 22.00	. .	. .	H	1	Zone Obs.
24	8 58 26.2	15 0.02	9 52 13.88	. .	. .	H	15	
26	8 50 51.6	15 17.29	9 54 59.39	. .	. .	H	15	Very faint.
27	8 47 7.2	15 28.88	9 56 11.44	. .	. .	H	15	Very faint.
Oct. 4	8 21 51.8	17 45.15	10 0 21.20	. .	. .	H	15	Very faint.

† Clock error from Transit Instrument.

OBSERVATIONS OF ASTEROIDS.

(15) EUNOMIA—(*continued*).

DATE.	M. T. Dudley Obs.	App. A. R.	App. Dec.	Δ α	Δ N. P. D.	Obs.	No. of Wires.	Remarks.
1864.	h m s	h m s	° ′ ″	s	″			
Aug. 15	9 18 21.4	18 57 16.39	—21 25 41.47	. .	. .	Mc	15	
27	8 27 27.7	18 53 32.96	20 45 10.54	. .	. .	H	1	† Cloudy.
30	8 15 25.3	53 18.27	20 35 4.90	. .	. .	H	15	
31	8 11 28.0	53 16.90	20 31 42.81	. .	. .	H	15	
Sept. 1	8 7 32.8	53 17.55	20 28 22.24	. .	. .	H	15	Faint.
8	7 40 55.9	54 12.15	20 5 9.21	. .	. .	H	15	
10	7 33 35.5	54 43.70	19 58 28.45	. .	. .	H	15	
			(16) PSYCHE.					
July 12	12 50 30.3	20 15 57.33	—17 9 21.62	. .	. .	H	15	
Aug. 15	10 10 16.6	19 49 20.10	19 4 52.43	. .	. .	Mc	15	
23	9 34 41.8	45 11.88	19 26 45.84	. .	. .	H	15	
30	9 4 47.8	42 48.86	19 42 50.11	. .	. .	H	15	
Sept. 1	8 56 29.1	42 21.95	. . . .	. .	. .	H	2	Clouds, very faint.
8	8 28 14.0	41 38.05	19 58 29.31	. .	. .	H	15	
10	8 20 24.2	41 40.11	20 1 13.79	. .	. .	H	15	
16	7 57 32.6	42 24.06	20 7 32.73	. .	. .	H	15	
17	7 53 49.5	42 36.88	20 8 20.79	. .	. .	Mc	5	
19	7 46 28.2	43 7.44	20 9 43.95	. .	. .	H	15	Very faint.

(43) ARIADNE.

Sept. 19	9 17 58. 5	21 14 52. 75	— 9 43 14. 40	. .	. .	H	1	Zone Obs.
20	9 14 0. 1	14 50. 30	9 45 22. 00	. .	. .	H	1	Zone Obs.
24	8 58 26. 2	15 0. 02	9 52 13. 88	. .	. .	H	15	
26	8 50 51. 6	15 17. 29	9 54 59. 39	. .	. .	H	15	Very faint.
27	8 47 7. 2	15 28. 88	9 56 11. 44	. .	. .	H	15	Very faint.
Oct. 4	8 21 51. 8	17 45. 15	10 0 21. 20	. .	. .	H	15	Very faint.

† Clock error from Transit Instrument.

The remaining observations have been made with the Declinometer, attached to the Meridian Circle.

The advantage of the latter method lies in the fact, that many bisections and readings can be made during the time of transit. The observations are not corrected for parallax.

The following example will show the method of observation with the Declinometer:

August 15th 1862. Comet II, observed on the meridian at the lower Culmination.

The first column is the number of bisections; the second H, hour angle; third, Declinometer scale reading; fourth, R, reduction to the meridian; fifth, scale reading reduced; sixth, R. m., reduction for Comet's motion; seventh, scale reading reduced to the meridian.

The mean of the seventh column gives the final scale reading for the position of the Comet if observed at the middle wire.

No. of Bisection.	H.	Scale.	R.	Scale reduced.	R. m.	Scale reduced for Comet's motion.
	m. s.	′ ″	″	′	″	
2	—6 48	22 16.25	—9.94	22 6.31	—6.80	21 59.59
2	—5 22	14.00	—7.95	6.05	—5.37	60.68
2	—4 35	12.50	—5.80	6.70	—4.59	62.11
2	—3 22	8.50	—3.13	5.37	—3.37	62.00
2	—2 32	6.75	—1.77	4.98	—2.50	62.48
2	—2 01	5.00	—1.12	3.88	—2.01	61.87
2	—1 22	4.50	—0.51	4.00	—1.33	62.67
2	—0 55	3.00	—0.25	2.75	—0.91	61.84
1	—0 20	3.00	—0.03	2.97	—0.33	62.64
1	—0 00	2.00	—0.00	2.00	—0.00	62.00
1	+0 20	2.00	—0.03	1.97	+0.33	62.30
2	+1 05	1.50	—0.32	1.18	+1.08	62.26
2	+1 22	1.75	—0.51	1.24	+1.33	62.57
2	+1 58	1.00	—1.05	21 59.95	+1.97	61.92
2	+2 38	2.50	—1.91	60.59	+2.63	63.22
2	+3 21	0.20	—3.09	57.11	+3.35	60.46
2	+3 57	2.75	—4.30	58.45	+3.95	62.40
2	+4 35	2.00	—5.80	56.20	+4.58	60.78
2	+5 13	3.85	—7.51	56.34	+5.22	61.54

OBSERVATIONS OF COMET II, 1861, MADE WITH TI
TORIAL.

DATE.	M. T. of Obs.	App. A. R.	App.
1861.	h m s	h m s	°
August 3	10 30 17.56	15 2 47.41	+ 47 2
10	10 54 35.16	15 10 38.48	. .
14	11 0 47.20	15 14 55.95	+ 45 :
15	9 57 45.91	15 15 57.44	. .

Aug. 3. Comp. *, 4961 Rumker. 3 Comp.
10. " 15266, 15309 Arg. 5 "
14. " 15272, 15290 Arg. 7 " {Co I:
15. " 15290 Arg. 6 " {Co I:

OBSERVATIONS OF COMET II, 1862, MADE WITH T
MERIDIAN CIRCLE.

The following observations have all been m: meridian, with the exception of July 18, when the observed with the wire micrometer of the equator

Star of comparison 10.5 mag.

Comet $\Delta\ \alpha = -6^s.45$. $\Delta\ \delta = +55''.2$:

18 comp. for A. R. and 10 comp. for Decl.

The place of the star was determined by three the lower culmination, observed with the Olc Circle.

* 10.5.	App. A. R.	A
1862.	h m s	
July 18	5 24 4.03	+ 6

The observations for A. R. are the mean ved by the magnetic method.

e declinations for July 25, 26, Aug. 3, 4, 10 : observed in the usual way, using eight